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VOL. XII, PART II

(April 1942)

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ORIGINAL ARTICLES

PROPERTIES OF SUB-FRACTIONS OF HYDROGEN CLAY PREPARED FROM INDIAN SOILS, I*

BY

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(Received for publication on 25 August 1941)

(With six text-figures)

IN recent years, the properties of sub-fractions of clay having particles of different sizes have attracted considerable attention in consequence of the light they throw on soil formation processes [Brown and Byers, 1932; Bradfield, 1935; Bray, 1937]. Apart from this standpoint, variations in colloidal properties with the particle size, even when the mass chemical composition of the disperse phase, the clay, shows little or no change with the degree of dispersion, are of considerable theoretical interest. A study of the properties of sub-fractions of hydrogen clays separated from Indian soils has been undertaken by us with both these objects in view. The present paper is the first of a series which will deal with these studies.

EXPERIMENTAL

(*a*) *Separation of sub-fractions from the entire clay fraction*—Particulars regarding the soils used are given below.

TABLE I

Particulars of soils used

Laboratory No.	Description of soil	*p*H		Clay + loss on solution (per cent)	Silt (per cent)	Base-exchange capacity by Parker's [1929] method	Total exchangeable bases (S) by Rice Williams' [1932] method
		Aq. suspension	*N*KCl suspension				
22	Red lateritic soil from Government Agric. Farm, Dacca (Bengal) collected from a depth of 0 to 6 inches	5·12	4·21	22·8	30·1	8·4	4·8
34	Black soil from Government Experimental Farm, Akola, Berar (C. P.) collected from a depth of 0 to 9 inches	7·10	7·05	44·8	19·6	39·5	39·5

*The results given in this paper have been taken from the published Annual Report for 1937-38 on the working of a scheme of research into the Properties of Colloid Soil Constituents financed by the Imperial Council of Agricultural Research, India

**Senior Assistant Soil Chemist under the above scheme

From the entire clay fractions of the soils the following subfractions were separated by controlled centrifugal subsidence. A ' bucket type ' centrifuge* having a diameter of 25 cm. and capable of making 5,000 revolutions per minute was used.

TABLE II

Equivalent spherical diameters of sub-fractions and their percentages in the entire clay fraction

Soil	Reference number of sub-fraction	Percentage of sub-fraction in the entire clay	Limiting equivalent spherical diameters in microns	Reference number of corresponding hydrogen clay
1. Red lateritic soil . .	1	25·10	0·26 and 2·0	L_1
	2	9·60	0·16 and 0·26	L_2
	3	65·40	<0·16	L_3
2. Black soil	1	13·50	0·45 and 2·0	M_1
	2	4·80	0·23 and ·045	M_2
	3	5·20	0·15 and 0·23	M_3
	4	75·50	<0·15	M_4

The depth of sampling and the rate of revolution of the centrifuge were kept constant in separating the different fractions ; only, the time of settling was varied. The limiting equivalent spherical diameters (given in column 4 of Table II) were calculated from Stokes' law under the following simplifying assumptions :

(*i*) The different fractions have the same density.

(*ii*) The particles settle under a uniform centrifugal force, viz. that obtaining at half height.

(*iii*) The particles have a spherical symmetry.

The different subfractions were leached with dilute (0·05*N*) hydrochloric acid to obtain the corresponding hydrogen clays which were washed free from HCl and made up to suspensions containing 2·5 gm. of oven-dried (105°C.) material per litre. All measurements reported in this paper were made with these hydrogen clays.

(*b*) *Fusion analysis for Fe, Al and Si.*—The usual methods of soil and clay analysis were followed [Wright, 1937].

(*c*) *Electrometric titration of hydrogen clays.*—The technique of Mukherjee *et al.* [1936] was followed. In addition to hydrogen and quinhydrone electrodes used by them glass electrodes (Morton type) in conjunction with a Cambridge electrometer valve potentiometer reading directly to 2 millivolts were used.

*A Sharples supercentrifuge is now being used for separating very fine sub-fractions

Results

(*a*) *Chemical composition.*—The results of fusion analysis are given in Table III.

Table III

Chemical compositions of the entire hydrogen clay and its sub-fractions isolated from the Dacca soil

Hydrogen clay	SiO_2 per cent	Al_2O_3 per cent	Fe_2O_3 per cent	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
L *	51·2	36·0	11·9	2·40	1·99
L_1	64·9	30·6	5·0	3·60	3·26
L_2	49·6	36·5	12·6	2·31	1·85
L_3	39·9	46·5	14·0	1·46	1·22

*Obtained from the entire clay fraction

Table IV

Chemical compositions of the entire hydrogen clay and its sub-fractions isolated from the Akola soil

Hydrogen clay	SiO_2 per cent	Al_2O_3 per cent	Fe_2O_3 per cent	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
M*	53·1	30·4	16·9	3·0	2·19
M_1	65·8	24·2	9·8	4·6	3·7
M_2	59·3	26·9	14·2	3·7	2·6
M_3	52·1	30·6	18·0	2·9	2·1
M_4	48·4	32·3	19·3	2·6	1·8

*Obtained from the entire clay fraction

The percentage of silica decreases with diminishing particle size while that of alumina and ferric oxide increases. In consequence, the silica-alumina and silica-sesquioxide ratios decrease with diminishing particle size. The percentage of silica is definitely higher in the coarsest fraction of the red soil and the two coarse fractions of the black soil compared with the respective entire clays. The percentages of Al_2O_3 and Fe_2O_3 are, on the other hand, greater in the entire clays than in the above coarse fractions but lower than in the finer fractions.

The results of fusion analysis of the silt fractions given in Table V follow the regular sequence of variations in composition with the particle size within the clay fraction.

TABLE V

Chemical compositions of the silt of the Dacca and Akola soils

	SiO_2 (per cent)	Al_2O_3 (per cent)	Fe_2O_3 (per cent)
Silt of the Dacca soil	90·4	6·76	1·42
Silt of the Akola soil	80·2	12·40	6·02

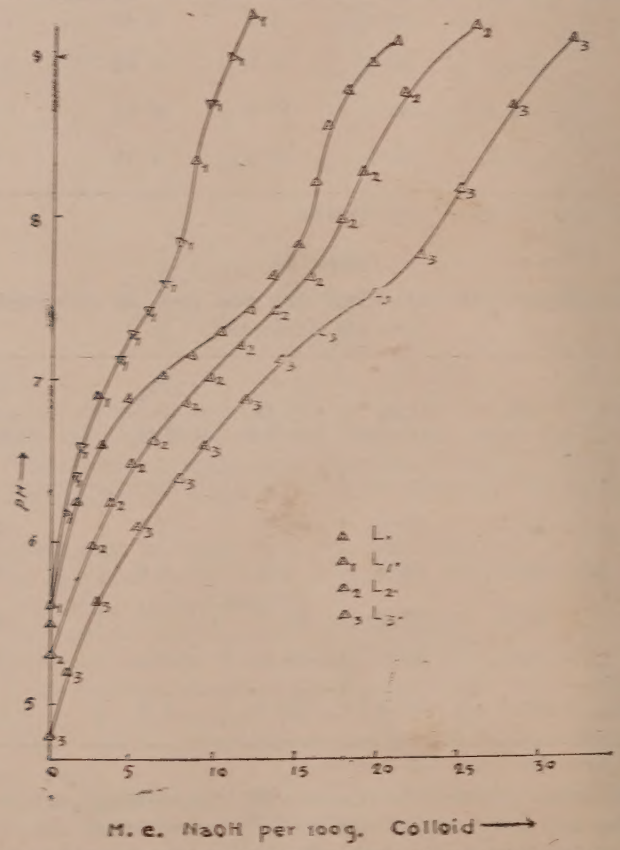

FIG. 1. Titration curves with NaOH of the entire hydrogen clay and its sub-fractions isolated from the Dacca lateritic soil

A similar increase in the percentage of silica in the silt fraction as compared with the 1-2 μ fraction was observed by Marshall [1935]. He attributed this to a greater percentage of free quartz in the silt.

The decrease in the percentage of silica with diminishing particle size indicates that the chemical weathering process attending the mechanical breakdown of the large particles is one of continued desilication which appears to be more pronounced with the red lateritic soil than the black soil in agreement with the more intense conditions of leaching under which the red soil has been formed compared with the other soil.

(*b*) *Free and total acids.*—Table VI gives the free acids calculated from the *p*H's of 0·25 per cent suspensions and the total neutralizable acids calculated from the titration curves with different bases given in Figs. 1-6. The total acids have been calculated both at the inflexion points of the curves as also at *p*H 7·0.

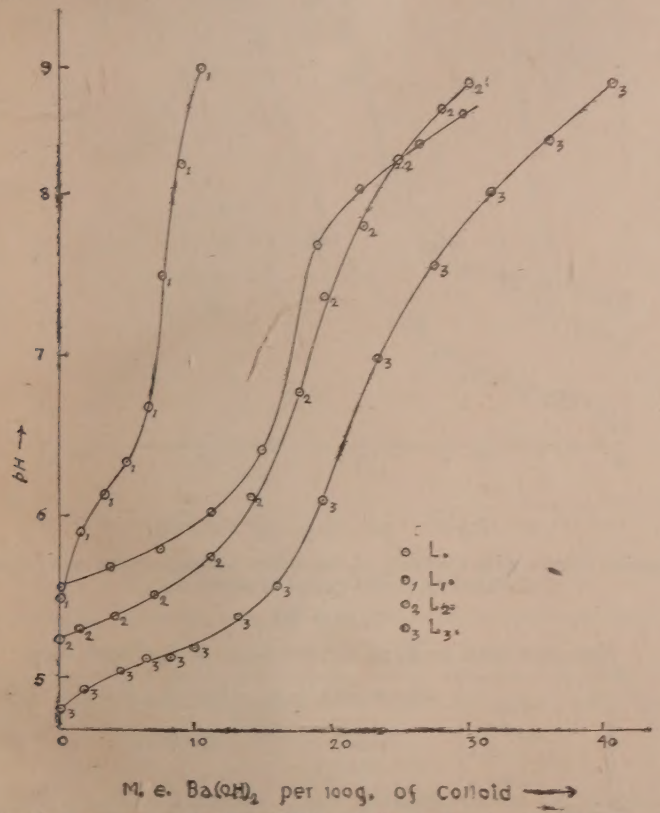

FIG. 2. Titration curves with Ba $(OH)_2$ of the entire hydrogen clay and its sub-fractions isolated from the Dacca lateritic soil

Both the free and total acids increase with diminishing particle size. L_1 and M_1 obtained from the coarsest fractions have much smaller total acids than L and M obtained from the entire clays. L_2 and L_3 have greater total acids than L. Those of M_2 and M_3 are small compared with M. M_4, however, gives a definitely greater value than M. The larger total acid of M compared with M_1, M_2 and M_3 is expected as the entire clay fraction is largely made up of the finest fraction (Table II) having the largest total acid.

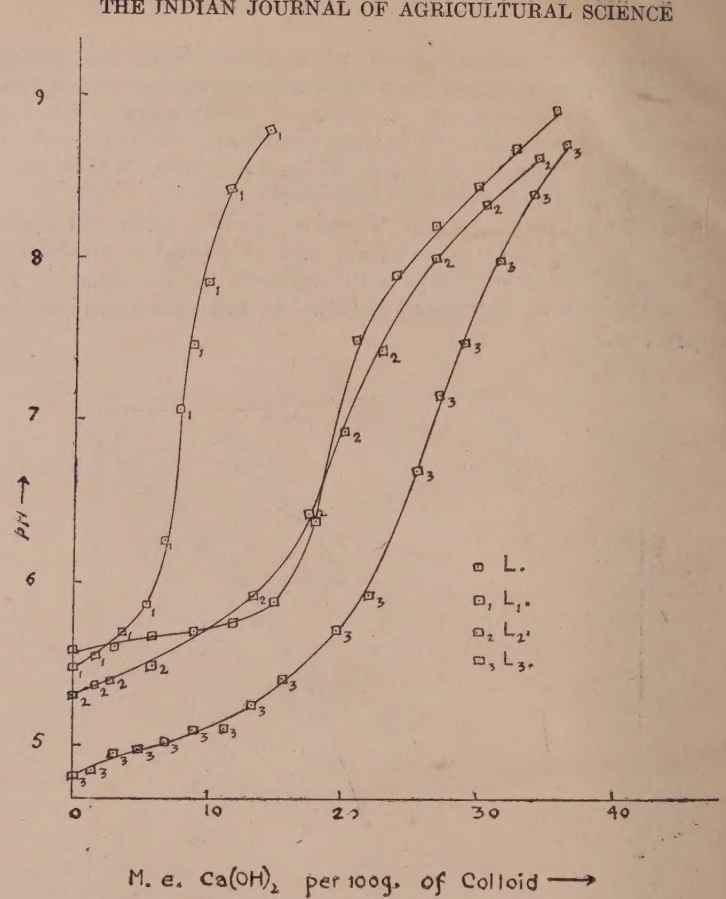

FIG. 3. Titration curves with $Ca(OH)_2$ of the entire hydrogen clay and its sub-fraction isolated from the Dacca lateritic soil

TABLE VI

Free and total acids of sub-fractions of hydrogen clay

Hydrogen clay	$\frac{SiO_2}{Al_2O_3}$ (molar)	Free acid in m. e. H+ ions per 100 gm. colloid	Total acid in m. e. base per 100 gm. colloid using					
			NaOH		$Ba(OH)_2$		$Ca(OH)_2$	
			At inflexion point	At *p*H 7·0	At inflexion point	At *p*H 7·0	At inflexion point	At *p*H 7·0
L_1	3·60	0·07	8·33	3·30	7·0	7·0	8·0	8·0
L_2	2·31	0·17	17·60	9·03	18·0	18·6	20·2	20·2
L_3	1·46	0·60	24·00	12·65	19·6	23·8	26·0	26·6
M_1	4·60	0·08	3·80	3·70	2·8	5·0	3·5	5·3
M_2	3·70	0·21	14·00	10·00	12·6	13·0	13·6	14·7
M_3	2·9	1·10	36·5	31·50	30·5	33·5	31·5	38·5
M_4	2·5	4·38	86·0	86·00	86·0	97·0	90·0	98·5

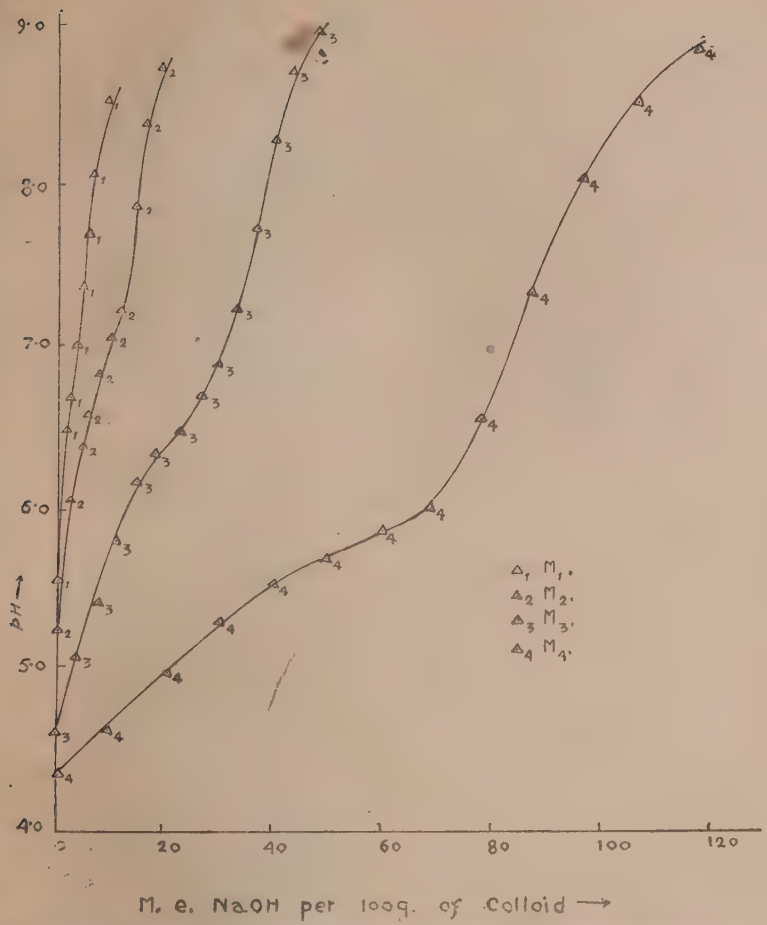

FIG. 4. Titration curves with NaOH of sub-fractions of hydrogen clay isolated from the Akola soil

In Table VII the observed total acids of L and M have been compared with their total acids calculated from those of the sub-fractions and the percentages of these sub-fractions in the entire clays.

TABLE VII

Total acids of entire hydrogen clays calculated from their titration curves and from those of their sub-fractions

Hydrogen clay	Total acid (at *p*H 7·0) in m. e. base per 100 gm. colloid using					
	NaOH		$Ba(OH)_2$		$Ca(OH)_2$	
	Observed	Calculated	Observed	Calculated	Observed	Calculated
L	6·3	9·9	17·0	19·0	19·5	21·3
M	60·0	67·0	79·0	75·2	87·0	77.0

The observed and calculated values show a fair agreement ignoring the total acids of L with NaOH and of M with $Ca(OH)_2$.

(*c*) *Form of titration curves.*—Previous work from this laboratory has dealt with the titration curves of hydrogen clays obtained from entire clay fractions [Mitra, 1936, 1940; Mukherjee, Mitra and Mukherjee, 1937]. A comparison of the titration curves of sub-fractions of hydrogen clay obtained from the same soil may afford useful information regarding the nature of the reactive acidic material present in the different fractions. Such comparative studies have not been previously made.

The NaOH curves of L_1, L_2 and L_3 given in Fig. 1 are similar to one another and to that of L obtained from the entire clay fraction. This is also true of M_1, M_2, M_3, M_4 and M given in Fig. 4. This similarity suggests that the same acid is being titrated in the different sub-fractions. This conclusion, however, does not apparently harmonize (further discussed later) with their markedly different chemical compositions given in Tables III and IV.

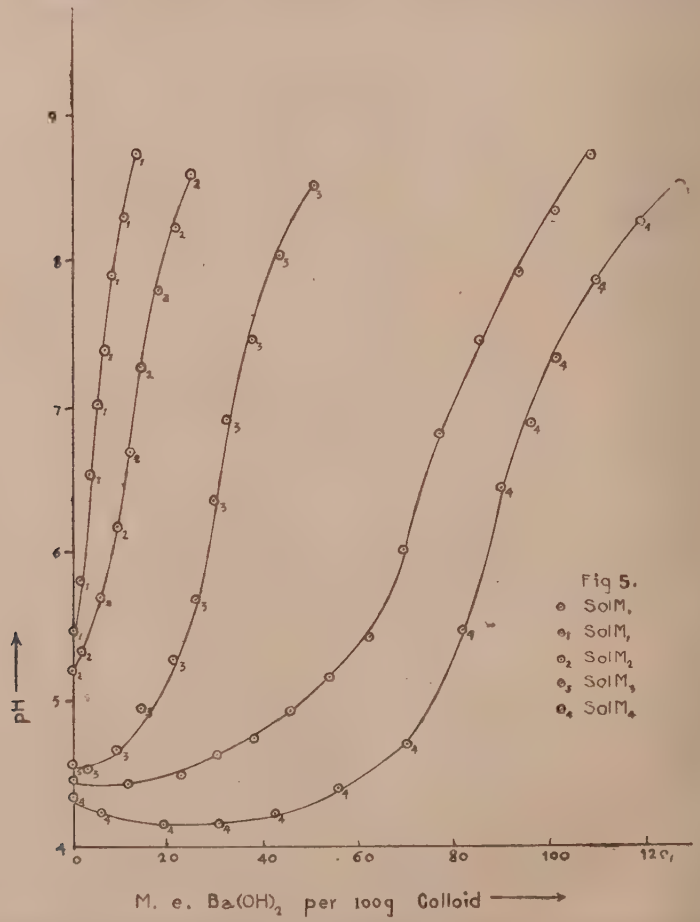

Fig. 5. Titration curves with $Ba(OH)_2$ of the entire hydrogen clay and its sub-fractions isolated from the Akola soil

The NaOH curves all have an apparent weak monobasic acid character. ble VIII shows the *p*H at their inflexion points and the apparent dissocia- n constants calculated from the *p*H's at half neutralization.

TABLE VIII

pH at inflexion and dissociation constants of hydrogen clays

Sol	*p*H at inflexion	*p*H (= *pK*) at half neutralization	*K*
L	8·21	7·13	$7·41 \times 10^{-8}$
L_1	8·10	7·15	$7·10 \times 10^{-8}$
L_2	8·00	6·97	$1·07 \times 10^{-7}$
L_3	8·03	6·96	$1·10 \times 10^{-7}$
M	7·49	6·20	$6·31 \times 10^{-7}$
M_1	7·10	6·56	$2·75 \times 10^{-7}$
M_2	7·63	6·66	$2·20 \times 10^{-7}$
M_3	7·60	6·26	$5·50 \times 10^{-7}$
M_4	7·00	5·56	$2·75 \times 10^{-6}$

The inflexion points in the titration curves of L, L_1, L_2 and L_3 occur within narrow range of *p*H (8·00-8·21) and the dissociation constants calculated m the curves are in fair agreement. With M, M_1, M_2, M_3 and M_4 the flexion points are located within a wider range of *p*H (7·00—7·63) though e agreement between the dissociation constants is not unsatisfactory ex- pting the finest fraction (M_4) whose dissociation constant is ten times that the coarsest. The dissociation constant has a tendency to increase with inishing particle size. This is true of the sub-fractions obtained from her soil.

The buffer capacity curves of the various sub-fractions obtained on tting the buffer capacity, β ($\beta = \Delta\beta/\Delta p$H) against the amount of the base aOH) added show definite maxima. In Table IX the maximum buffer pacities (β max.) of the various sub-fractions, as also the *p*H and the per- ntage neutralization at maximum buffer capacity, have been compared.

TABLE IX

aximum buffer capacity, and p*H and per cent neutralization at maximum buffer capacity of hydrogen clays*

Sol	β max.	*p*H at β max.	Per cent neutralization at β max.
L_1	5·8	7·45	69·6
L_2	11·0	7·20	62·5
L_3	19·0	7·50	79·1
L	10·5	7·30	64·6
M_1	5·0	6·68	65·7
M_2	10·5	6·90	71·4
M_3	26·0	6·70	71·2
M_4	66·0	5·63	60·5
M	50·0	6·45	66·0

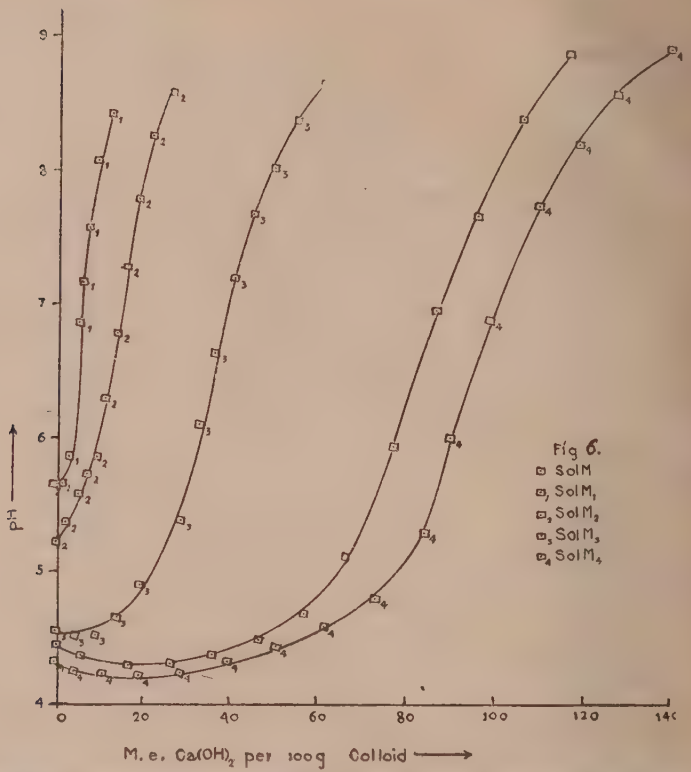

Fig. 6. Titration curves with $Ca(OH)_2$ of the entire hydrogen clay and its su fractions isolated from the Akola soil

The finer the fraction, the higher is β max. With L_1, L_2, L_3 and L, max. occurs within a small range of *p*H. This is also true of M_1, M_2, M_3 an M. β max. of M_4, however, occurs at a much lower *p*H compared with th other hydrogen clays. It is to be noted that β max. in no case correspond to 50 per cent neutralization as would be expected in the case of a dissolve weak acid. It occurs at a higher stage of neutralization (60 to 80 per cent Evidently, the interaction of the hydrogen clays with the base is not simple neutralization of H^+ by OH^- ions. It is complicated by other factor [Mukherjee, Mitra and Mukherjee, 1937.]

The $Ba(OH)_2$ curves of L_1, L_2, L_3 and L given in Fig. 2 are not all quit similar. Those of L_1 and L_3 have an apparent weak acid character. L and L_2 on the other hand, behave as strong acids. The dissociation constant calculate from the *p*H at half neutralization is $6{\cdot}7 \times 10^{-7}$ for L_1 and $5{\cdot}5 \times 10^{-6}$ fo L_3. The finer fraction thus behaves as a stronger acid.

The $Ca(OH)_2$ curves of L, L_1 and L_2 have the same form which different from that of sol L_3 (Fig. 3).

The $Ba(OH)_2$ and $Ca(OH)_2$ curves of M_1, M_2, M_3, M_4 and M given i Figs. 5 and 6 show a general similarity of form. Those of M, M_2, M_3 an M_4 present one peculiar feature, viz. that on the first addition of the base, th

H of the sol instead of increasing or remaining constant shows a definite ecrease. This is specially marked with the baryta curves of the finer fractions. Acid appears to be liberated as a result of the interaction between the ol and the base, a result which is foreign to classical principles of acid-base nteractions. An explanation of the observation is deferred pending completion of further investigations now in progress.

(*d*) *Total acidity per gramme and per sq. cm. of surface.*—The increase the total acid with diminishing particle size (Table VI) may be referred to an ncrease in the specific surface and hence to a greater number of exchange pots in a given area. In Table X the total acids of the sub-fractions from the lack soil calculated per gramme (T_g) and per sq. cm. of the surface (T_s) have een compared.

TABLE X

Specific surface and b. e. c. per gm. and per sq. cm. of surface of hydrogen clays

Hydrogen clay	Average sp. surface in sq. cm × 10^3	Total acid in m. e. NaOH at inflexion point	
		per gm. (T_g)	per sq. cm × 10^7 (T_s)
M_1	18·5	0·038	20·5
M_2	66·5	0·140	21·0
M_3	120·0	0·365	30·0
M_4	>160·0	0·860	<55·0

It will be seen that T_s does not show any marked or regular variation with he particle size* though T_g rapidly increases as the latter decreases.

GENERAL DISCUSSION

The variations in the total acid per gramme with the particle size may rise from variations in the nature of the reactive material making up the arious fractions as the differences in chemical composition would also suggest. The similarity in the form of the titration curves of the different fractions, pecially the NaOH curves, and the fair agreement between the values of he dissociation constant calculated from them, on the other hand, indicate hat the active acidic material present in the different fractions is essentially he same. Considered in this light the variations in the total acid (per gramme) and chemical composition may be due to varying admixtures of 'free' silica and sesquioxides having negligible base-combining capacity in he different fractions. The differences in composition might also arise from somorphous replacements [Marshall, 1935] within the lattice of the constituent minerals and/or differences in relative proportions of several types of

*Variations in T_s have been observed using sub-fractions from other soils. These will be discussed in the next paper of this series

clay minerals in the different fractions but these would probably give rise more marked variations in the form of the titration curves than observed this work.

Summary

The variations in chemical composition, form of titration curves wi bases and the base exchange capacities (b.e.c.) calculated from these curv of hydrogen clays prepared from three and four sub-fractions respectively the entire clay fraction of a red lateritic soil from Dacca (Bengal) and a bla soil from Akola (Central Provinces) have been studied. As the particle si decreases, the percentage of Al_2O_3 increases but that of SiO_2 and Fe_2 diminishes as also the silica-sesquioxide ratio. The b. e. c. and the amou of free H^+ ions calculated per gramme rapidly increase with diminishi particle size but calculated per square centimetre of the external surfac the b. e. c. shows no marked or regular variation. The different sub-fractio prepared from the same soil give nearly the same type of titration curves.

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TERATIONS IN THE PROPERTIES OF HYDROGEN CLAYS ON THE REMOVAL OF FREE INORGANIC OXIDES CONTAINED IN THEM, I *

BY

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(With five text-figures)

inorganic colloidal material of soil, besides containing Si, Al and Fe a combined form making up its mineral constituents proper, is often ated with varying amounts of free oxides of these elements. The f these free oxides in determining the base exchange and other rties of the soil colloidal material is not very well understood. A natic study has been undertaken of the changes in properties drogen clays consequent on the removal of the free oxides con- in them. The methods usually used for this purpose are not s free from the criticism that they may decompose, or, alter the proper- the clay minerals and may not effect a complete separation of the oxides. te of these limitations it is of interest to examine the changes brought by such separations. The present paper deals with changes consequent atments according to the methods of Tamm [1922], Mattson [1931], and off and Truog [1935] for the removal of the free oxides. The following rties have been studied : (*i*) chemical composition, (*ii*) the form of iometric titration curves with bases and (*iii*) the base exchange capacity ated from these curves. The hydrogen clays used are listed on the next Further results will be reported in subsequent papers of this series.

Experimental

) Separation of the free inorganic oxides.—Tamm uses a solution of mmonium oxalate having a *p*H 2·32. In Mattson's method which is or the separation of the free sesquioxides only the clay is treated with a aturated solution of aluminium chloride. In the method of Drosdoff ruog, free silica and alumina are first removed by digestion at 70°C., with cent solution of sodium carbonate. The free ferric oxide is then removed n sulphide which is formed on passing H_2S gas through an aqueous sus- on of the clay.

The results given in this paper have been taken from the published Annual Reports 5-36, 1936-37 and 1938-39 on the working of a scheme of research financed by the al Council of Agricultural Research, India.

enior Assistant Soil Chemist under the above scheme

Reference No. of hydrogen clay (before removal of free oxides)	SiO_2/R_2O_3 ratio of hydrogen clay	Lab. No. and description of soil from which hydrogen clay was obtained
F	1·94	High land acid soil from Government Farm, Burdwa (Bengal) collected at a depth of 0—6 inch from Block B, Plot No. 40. Lab. No. 14
I	2·50	Neutral calcareous soil from Satara distri (Bombay) collected at a depth of 0—6 inche Lab. No. 25
K	2·54	Neutral black soil from Bilaspur near Raipur (C. P collected at a depth of 0—6 inches. Lab. No. 3
L	1·99	Red lateritic soil from Government Farm at Dac (Bengal) collected at a depth of 0—6 inches. La No. 22
N	1·88	Bhata red laterite soil from C. P. collected at a dep of 0—9 inches. Lab. No. 33

(*b*) *Preparation of hydrogen clays.*—Hydrogen clays were prepared fro the entire clay fractions (before and after removal of their free oxides) b leaching them with 0·02*N* hydrochloric acid. In the sequel, the subscripts *b* and *c* to the reference numbers of hydrogen clays have been used to deno those prepared after removal of the free oxides by the methods of Mattso Tamm, and Drosdoff and Truog respectively.

(*c*) *Chemical analysis.*—The percentages of SiO_2, Al_2O_3 and Fe_2O_3 in t hydrogen clays have been determined after fusion with sodium carbona [Wright, 1937].

(*d*) *Electrometric titration of hydrogen clays.*—Details of procedure adopt for this work have been described elsewhere [Mukherjee *et al.*, 1936 ; Mit 1936, 1940]. Hydrogen and glass electrodes were used.

Results

A. Hydrogen clays prepared from the Burdwan Farm soil (Lab. No. 14)

The free oxides were removed by Tamm's method. Figs. 1 and give the titration curves with bases. The base exchange capacities* (b.e. calculated from the curves are given in Table I and the results of fusi analysis in Table II.

Table I

Base exchange capacities of hydrogen clay from Burdwan soil before and after removal of free oxides

Hydrogen clay	Base used for titration	*p*H at inflexion	B.e.c. in m.e. base p 100 gm. colloid at in flexion point of tit ration curve
F . . .	NaOH . . .	6·15 ; 7·85	9·0 ; 31·6
	$Ba(OH)_2$ . .	7·0	31·0
F^b	NaOH . . .	4·7 ; 7·2	3·0 ; 25·0
	$Ba(OH)_2$ . .	5·0 ; 6·2	7·5 ; 25·0
	$Ca(OH)_2$ . .	6·2	25·0

* Reproducible to within ±2·5 per cent

TABLE II

Chemical composition of hydrogen clay from Burdwan soil before and after removal of free oxides

ydrogen clay	SiO_2 per cent	Al_2O_3 per cent	Fe_2O_3 per cent	SiO_2/Al_2O_3 (molar)	SiO_2/R_2O_3 (molar)
. . .	49·2	29·2	21·4	2·85	1·94
. . .	51·5	30·9	17·4	2·82	2·01

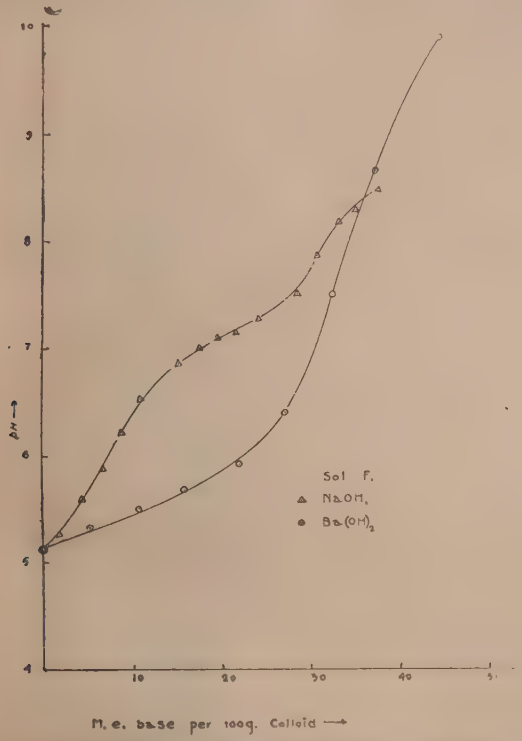


FIG. 1. Titration curves of hydrogen clay from Burdwan soil before removal of free oxides

The changes consequent on the removal of the free oxides may be summed as follows :

	SiO_2 (per cent)	Al_2O_3 (per cent)	Fe_2O_3 (per cent)
Chemical composition	$F_b > F$	$F_b > F$	$F_b < F$
Base exchange capacity .	$F_b < F$		
Form of titration curves . . .	The curves of F_b show a weaker initial buffer action than those of F ; the $Ba(OH)_2$ curve of F_b shows a dibasic acid character not observed with F		

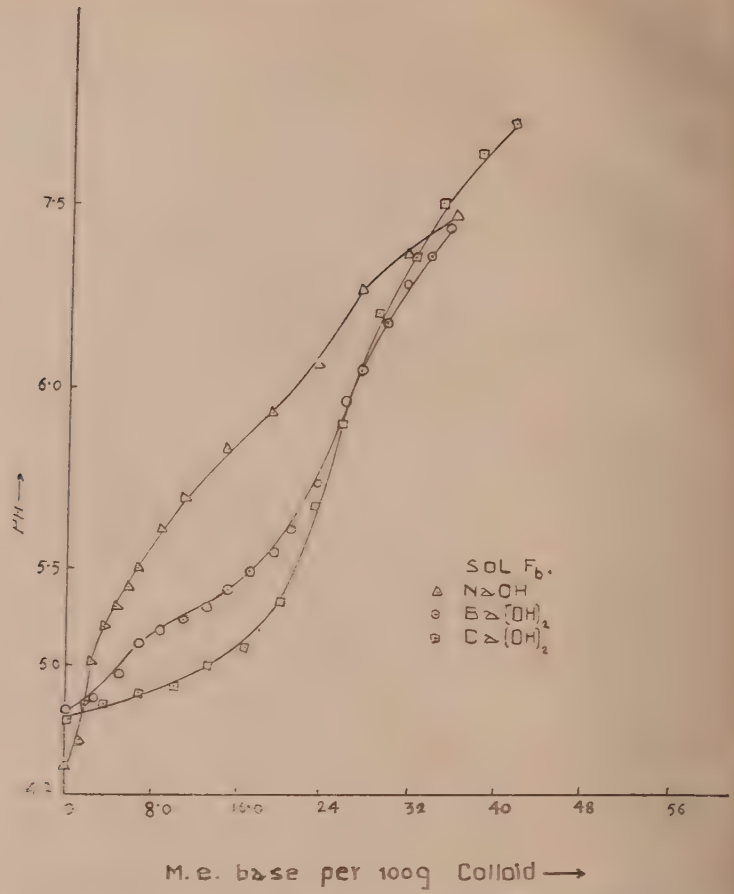


FIG. 2. Titration curves of hydrogen clay from Burdwan soil after removal of free oxides by Tamm's method

The alterations in chemical composition and the form of the titration curves point to a definite change in the hydrogen clay as a result of the treatment. The decrease in the b.e.c. suggests that this treatment brings about a decomposition of the exchange complex ; an increase would have been observed if only free oxides having little or no base combining capacity had been removed

B. Hydrogen clays prepared from the black cotton soil from Satara (Lab. No. 25) and the black soil from Raipur (Lab. No. 32)

The free oxides were removed by the method of Drosdoff and Truog. The base exchange capacities of I and K and their derivatives I_c and K_c calculated from the titration curves have been given in Table III and the results of fusion analysis in Table IV. All the four hydrogen clays give the same

type of titration curve with any given base. The titration curves of I_c only are given in Fig. 3.

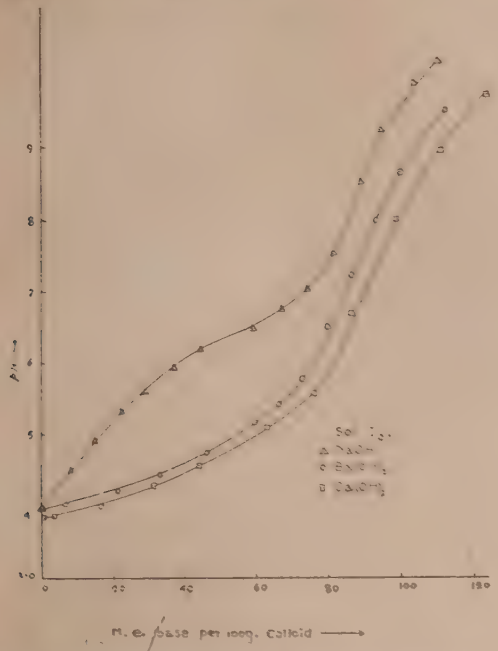


FIG. 3. Titration curves of hydrogen clay from the Satara soil after removal of free oxides by Drosdoff and Truog's method

TABLE III

Base exchange capacities of hydrogen clays from the Satara and Raipur soils before and after removal of free oxides by Drosdoff and Truog's method

Hydrogen clay	Base used for titration	*p*H at inflexion point in the titration curve	B.e.c. in m.e. base per 100 gm. oven-dried colloid	
			At inflexion point	At *p*H 7·0
I	NaOH	8·05	90·0	78·0
	$Ba(OH)_2$	7·00	82·0	82·0
	$Ca(OH)_2$	6·95	96·0	97·0
I_c	NaOH	8·10	86·0	74·0
	$Ba(OH)_2$	7·60	91·0	85·0
	$Ca(OH)_2$	6·50	86·0	91·0
K	NaOH	7·15	68·0	67·0
	$Ba(OH)_2$	5·80	55·0	61·0
	$Ca(OH)_2$	5·20	58·0	67·0
K_c	NaOH	8·10	67·5	60·0
	$Ba(OH)_2$	5·75	56·0	62·0
	$Ca(OH)_2$	5·78	63·0	68·0

TABLE IV

Chemical compositions of hydrogen clays from the Satara and Raipur soils before and after removal of free oxides

Hydrogen clay	SiO_2 per cent	Al_2O_3 per cent	Fe_2O_3 per cent	SiO_2/R_2O_3 (molar)	SiO_2/Al_2O_3 (molar)
I . . .	55·03	24·20	20·81	2·50	3·87
Ic . . .	55·95	24·57	18·71	2·54	3·72
K . . .	55·93	28·03	14·80	2·54	3·40
Kc . . .	58·30	26·90	15·80	2·66	3·65

The changes consequent on the treatment are summed up in the char given on the next page.

If the alterations in chemical composition merely indicated a removal o free oxides which are considered to have little base combining power, an in crease in the b.e.c. would be expected. The b.e.c. of the Satara hydrogen clay actually shows a slight decrease* which probably indicates that a decomposi tion of the exchange complex is responsible for the variation in chemical com position. The b.e.c. of the other hydrogen clay remains practically unaltered and in order to reconcile this result with the small but definite variation in the chemical composition, it has to be assumed that the substances removed by the treatment were not ' inert '; they had, mass for mass, nearly the same b.e.c. as the original hydrogen clay.

C. Hydrogen clays prepared from the Bhata laterite soil (Lab. No. 33) and the red lateritic soil from Dacca (Lab. No. 22)

Laterite soils usually contain free sesquioxides. Mattson's method was therefore used in the case of the above two hydrogen clays.

The b.e.c.'s of L and N and their derivatives L_a and N_a are given in Table V and the results of fusion analysis in Table VI. Figs. 4 and 5 show the titration curves of L and L_a. The titration curves of the other two hydro gen clays are similar to those of L and have been omitted.

*Except for the slight increase in the b.e.c. at *p*H 7·0 with $Ba(OH)_2$; this increase however, is almost within the limits of experimental error (±2·5 per cent)

Hydrogen clay from	Chemical composition			B.e.c. with						Form of titration curves with bases
				NaOH		$Ba(OH)_2$		$Ca(OH)_2$		
	SiO_2 per cent	Al_2O_3 per cent	Fe_2O_3 per cent	At inflexion point	At *p*H 7·0	At inflexion point	At *p*H 7·0	At inflexion point	At *p*H 7·0	
1. Black cotton soil from Satara	Increases	Increases	Decreases	Slightly decreases	Slightly decreases	Increases but the *p*H at inflexion after removal of free oxides is definitely higher	Slightly increases	Decreases	Decreases	The form of the curves remians practically unaltered except for variations in the *p*H's at the inflexion point
2. Black soil from Raipur	Increases	Decreases	Increases	No change though the *p*H at inflexion after removal of free oxides is higher	Decreases	No change	No change	Increases but *p*H at inflexion after removal of free oxides is higher	No change	

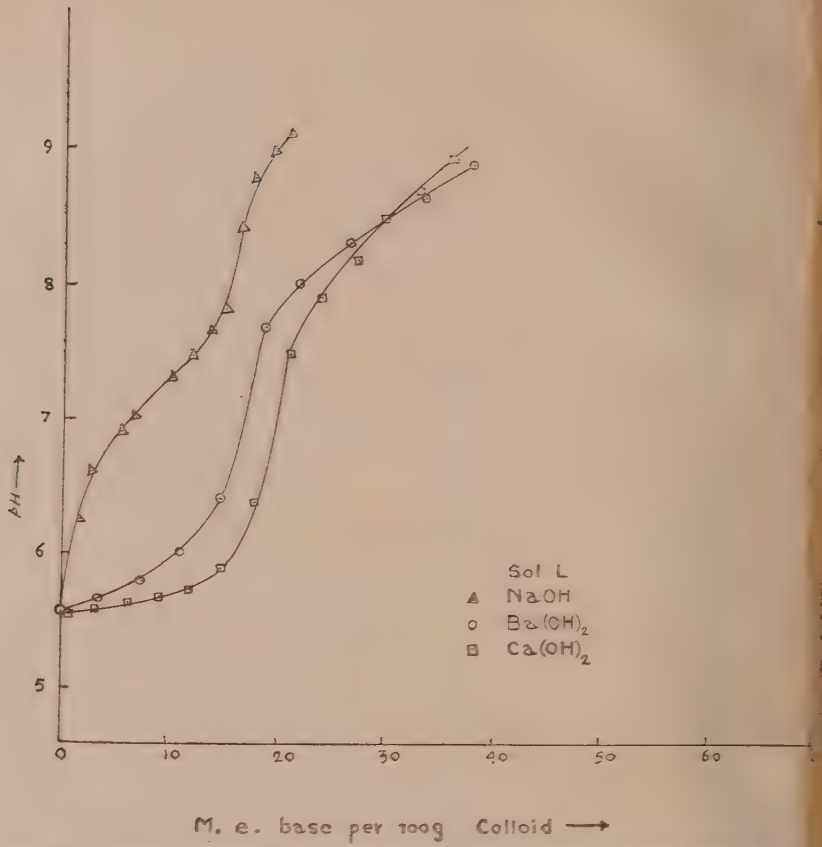


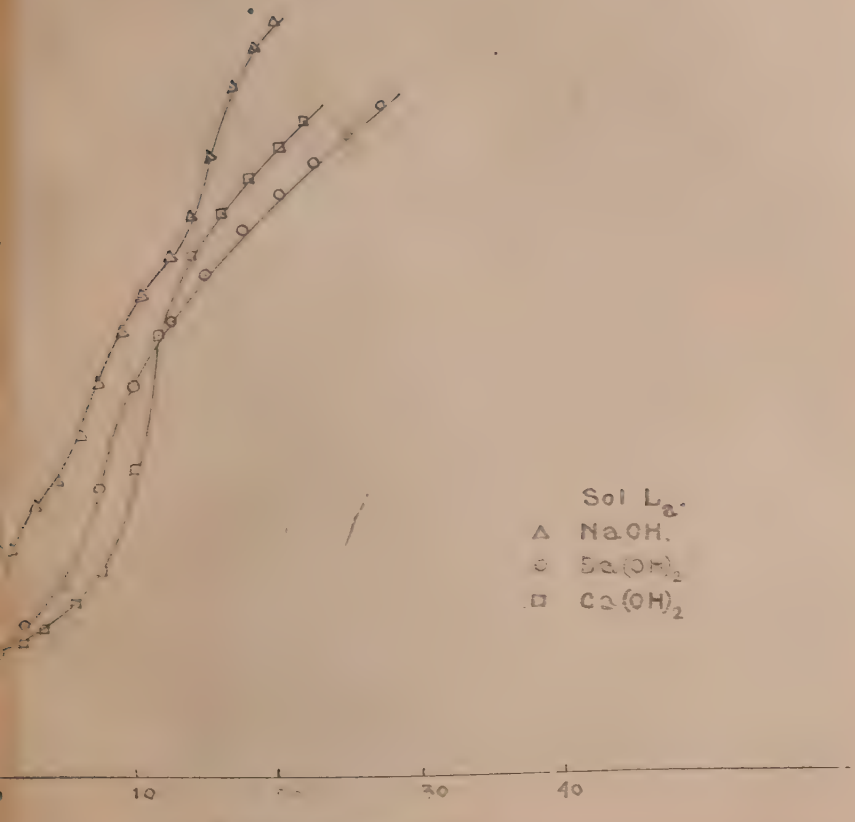
FIG. 4. Titration curves of hydrogen clay from Dacca soil before removal of fr oxides

TABLE V

B.e.c. in m.e. base per 100 gm. of hydrogen clays from Dacca and Bhata before and after removal of free oxides by Mattson's method

Hydrogen clay	Base used					
	NaOH		$Ba(OH)_2$		$Ca(OH)_2$	
	At inflexion point	At *p*H 7·0	At inflexion point	At *p*H 7·0	At inflexion point	At *p*H
L . .	16 25	6·3	17·5	17·0	19·0	19·
L_a . .	7*; 6·0**	6·8	8·5	9·0	11·5	11
N . .	18·	11·3	19·0	19·0	2)·5	21·
N_a . .	11	7·5	15·3	15·3	17·5	18·

*Calculated from the first inflexion point
**Calculated from the second inflexion point



IG. 5. Titration curves of hydrogen clay from Dacca soil after removal of free oxides by Mattson's method

TABLE VI

ical compositions of hydrogen clays from Dacca and Bhata soils before and after removal of free oxides

irogen clay	SiO_2 (per cent)	Al_2O_3 (per cent)	Fe_2O_3 (per cent)
. .	51·2	36·0	12·0
. .	50·0	38·8	10·1
. .	42·6	3·70	54·2
. .	42·0	4·50	53·4

The percentage of silica and ferric oxide decreases as a result of the tr ment, while that of alumina increases. The b.e.c. of both L and N decrea If only free sesquioxides having negligible b.e.c. were removed, an increas the b.e.c. would have been observed. The treatment also brings abou material change in the form of the NaOH curve of L. While L behaves weak monobasic acid judging from this curve, its derivative L_a show dibasic acid character.

Attention may finally be drawn to one general feature observed wi the hydrogen clays both before and after the treatments for the remova their free oxides. At any given *p*H, the slopes of their titration curves w different bases are usually arranged in the order $NaOH > Ba(OH)_2 > Ca(O$ which shows that these three bases react with the hydrogen clays in the verse order. This difference in the relative effects of the three bases illustra what has been designated by us as an irregular or specific cation effect. has been fully discussed elsewhere [Mitra, 1936, 1940 ; Mukherjee, Mitra Mukherjee, 1937].

Summary

A study has been made of the effect of treatments aiming at the remo of free silica and sesquioxides contained in hydrogen clays on their chem composition, nature of titration curves with bases and base exchange capac (b.e.c.). Hydrogen clays prepared from the entire clay fraction of five Ind soils have been used and the methods of Tamm, Drosdoff and Truog, Mattson were employed for the removal of the free oxides. Tamm's meth gives rise to a decrease in the b.e.c. of a hydrogen clay from a Burdwan (Ben soil. The chemical composition and the form of the titration curves are materially altered indicating, on the whole, a decomposition of the excha complex as a result of the treatment. Practically no change occurs in b.e.c. and the nature of the titration curves of hydrogen clays from two bl cotton soils using the method of Drosdoff and Truog. Slight changes in chemical composition are, however, observed. Mattson's method gives r to a marked decrease in the b.e.c. of hydrogen clays from a red lateritic from Dacca (Bengal) and a red laterite soil from the Central Provinc The form of the titration curve with caustic soda of the hydrogen clay fr the Dacca soil is also altered.

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STUDIES IN KUMAUN HILL SOILS

III. SOIL TYPES AT DOONAGIRI

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HE soil survey work reported by us for Chaubattia in the first two parts of this series of publication has also been extended to other parts of naun, and in the present paper a consolidated account of the soil types d at Doonagiri is discussed. The technique of our survey and the methods lved have already been described in detail in the previous papers, and in present instance only a bare outline of these will be given.

Doonagiri lies north of Chaubattia at a distance of 16 miles as the crow

The parent material of the soils is phyllite ; granite gneiss has been d at only a few places. Although a large number of soils studied by us clayey, due to high content of organic matter, the soils, however, are not rated. The general forest flora of the locality is very much similar to e of Chaubattia. Average rainfall is over 60 inches a year. Situated ner interior into the hills, and being a little higher, the climate of Doona- is slightly cooler and comparatively more humid than that of Chaubattia. The estate was deforested in about 1867 and planted to tea. After about ears due to transport and other difficulties the plantation was aban- ed, and no attempt has since been made to rehabilitate the area.

Literature

Information on hill soils is very scanty and the literature suffers from city of data. The present position of the work on hill soils was summarized he two foregoing papers of this series [Mukerji and Das, 1940 ; 1941], and ttempt has, therefore, been made here to review the literature.

The importance of the clay fraction in soil characterization was shown by nson [1930] for certain profiles of north Wales. Various authors have e utilized this method for the classification of soil profiles studied by them. ntly Mukerji and Das [1940 ; 1941] in their studies on hill soils have shown seefulness of SiO_2/R_2O_3 ratio in determining the precise characteristics of types in the Himalayan foot-hills in the United Provinces.

Analytical methods

Clay

International pipette method was used for the determination of content of soils. After preliminary treatment with hydrogen peroxide hydrochloric acid, dispersion was brought about by ammonia.

Organic carbon

Walkley and Black's method [1934] was used for this determination.

pH

*p*H values were determined by means of quinhydrone electrode.

Sesquioxides

For the determination of sesquioxides, HCl digestion was done accor to the method of Agricultural Education Association.

Base-saturation

Barium acetate and ammonium chloride method of Parker [1929] utilized for the determination of exchangeable acidity and base-excha capacity in the same sample.

Clay composition

Robinson's method [Wright, 1939] was followed, and sesquioxides silica were determined by the usual method for estimating silicates.

Data and discussions

A large number of soil profiles were examined at Doonagiri, and in succeeding pages a critical account of six profiles typical of the area wil given. It has been shown in the previous two papers of this series that sil sesquioxide ratios together with the figures for percentage base-satura give more or less an accurate idea of the local soil types. These data therefore, be examined for all the profiles studied along with such o relevant data as necessary.

Pit No. 2 : Doodhatoli

Horizon	Depth	Description
I . .	0-1 ft. 3 in. .	Grey ; granular ; loamy with a slightly bl ish tinge. Dark grey when wet
II . .	1 ft. 3 in.-2 ft. 3 in.	Same as above ; particles more granu appear to contain more organic matter above
III . .	2 ft. 3 in.-4 ft. 6 in.	Organic ; claycy loam ; dark grey. Co same as of the second horizon

TABLE I

Summarized analytical data of Doonagiri soils

(Pit No. 2)

ori-on	Per cent (air-dry basis)					C/N	pH
	Clay	Organic carbon	Total nitrogen	Fe_2O_3	Al_2O_3		
I	23·35	3·9	0·23	5·59	8·97	16·96	6·2
I	21·75	7·6	0·25	8·32	8·10	30·40	5·8
I	30·50	5·8	0·20	8·48	7·67	29·00	5·5

The general character of the profile is organic, and Wiesenboden characristics are revealed in C/N ratios. Clay content of different horizons, and squioxide distributions are rather erratic. The composition of clay fracon and base-saturation percentages of different horizons are given in Table

TABLE II

Clay analysis of Doonagiri soils

(Pit No. 2)

orizon	Per cent (air-dry basis)			$\frac{SiO_2}{R_2O_3}$	Exchangeable H (m. e. per cent on air-dry basis)	Per cent base-saturation
	SiO_2	Al_2O_3	Fe_2O_3			
I	44·48	19·88	15·97	2·51	4·21	75·56
I	43·90	20·93	16·77	2·35	7·25	54·69
I	43·20	26·23	16·37	2·00	8·70	54·69

These figures, particularly eluviation of Al_2O_3 and constancy of Fe_2O_3 in he profile, indicate that the third horizon is not of the same age as the first wo, and can be classified as a brown forest soil having podsolic tendencies.

Pit No. 3 : Doodhatoli

Horizon	Depth	Description
I	0-11 in.	Grey ; granular ; loamy ; dark grey when wet
II	11 in.-1 ft. 10 in.	Dark grey ; clayey ; loamy ; very dark grey when wet
III	1 ft. 10 in.-4 ft.	Dark grey ; granular ; loamy ; very dark grey when wet

TABLE III

Summarized analytical data of Doonagiri soil

(Pit No. 3)

Horizon	Per cent (air-dry basis)					C/N	*p*H
	Clay	Organic carbon	Total nitrogen	Fe_2O_3	Al_2O_3		
I	24·45	5·5	0·30	4·95	13·07	18·33	6·0
II	29·25	6·4	0·23	8·24	10·49	27·83	5·7
III	22·50	4·8	0·14	8·80	13·36	34·29	5·9

The predominant character of the entire profile is its organic matter co tent, and C/N ratio increases with depth. In this respect the pedologic characters of the two profiles examined at Doodhatoli are alike. Clay conte and *p*H values are rather erratic. Clay analysis figures of this profile and ba status are given in Table IV.

TABLE IV

Clay analysis and exchangeable bases of Doonagiri soils

(Pit No. 3)

Horizon	Per cent (air-dry basis)			$\frac{SiO_2}{R_2O_3}$	Exchangeable H (m.e. per cent on air-dry basis)	Per cent base-saturation
	SiO_2	Al_2O_3	Fe_2O_3			
I	45·74	18·23	15·57	2·75	7·98	65·33
II	43·86	25·43	15·97	2·10	7·25	60·39
III	42·08	27·63	17·97	1·82	5·80	67·78

It follows from figures given above that the second and third horizo show some of the typical characters of the brown forest soils having Wiese boden podsolic tendencies. The first horizon, however, does not appear be of the same age. A few more profiles were examined in this area and visual characters they were found to be similar to pit Nos. 2 and 3.

Pit No. 5 : Dadoi

Horizon	Depth	Description
I	0-10 in.	Grey ; granular ; loamy ; dark grey when wet
II	10 in.-1 ft. 5 in.	Grey with a slightly brownish tinge ; loamy ; conta more clay than the top ; more grey when wet
III	1 ft. 5 in.-3 ft.	Brownish ; granular ; clayey loam ; more brown when w

TABLE V

Summarized analytical data of Doonagiri soils

(Pit No. 5)

	Per cent (air-dry basis)					C/N	*p*H
	Clay	Organic carbon	Total nitrogen	Fe_2O_3	Al_2O_3		
I	25·40	2·81	0·18	5·35	13·63	15·61	6·0
II	32·85	1·9	0·15	8·32	8·39	12·62	5·6
III	36·50	1·4	0·08	8·48	10·28	17·50	5·4

It is clear from the above description and analytical data that these pro- are heavy brown forest soils, undisturbed by terracing operations, and very much affected by surface erosion. The composition of the clay frac-ns, as given in Table VI , indicates the real nature of the profile.

TABLE VI

Clay analysis and exchangeable bases of Doonagiri soils

(Pit No. 5)

Horizon	Per cent (air-dry basis)			$\frac{SiO_2}{R_2O_3}$	Exchangeable H (m. e. per cent air-dry basis)	Per cent base-saturation
	SiO_2	Al_2O_3	Fe_2O_3			
I	43·50	29·63	15·57	1·86	2·18	86·41
II	46·26	26·93	14·77	2·16	4·35	74·71
III	47·60	25·03	13·57	2·40	9·43	36·32

Although there is a slight indication of eluviation of silica, exchange lity and percentage base-saturation figures clearly bring out the brown est soil characteristics of the profile. The silicious material of the second l third horizons has sometimes been ascribed to colloidal SiO_2 of the parent terial. It is suggested that the excess of silica in the second and third izons of most of our soils is due to capillary ascendance of silica soil from lower layers.

No. 7 : Khalkhet

Horizon	Depth	Description
I	0-6 in. . . .	Grey ; granular ; loamy sand with a slightly brownish tinge with some clay ; dark grey when wet
II	6 in.-1 ft. 6 in. .	Same as above, but contains more clay
III	1 ft. 6 in.-2 ft. 6 in. and below. .	Brownish grey ; more granular, heavy loam

TABLE VII

Summarized analytical data on Doonagiri soils

(Pit No. 7)

Horizon	Per cent (air-dry basis)					C/N	pH
	Clay	Organic carbon	Total nitrogen	Fe_2O_3	Al_2O_3		
I	13·25	6·4	0·22	7·19	7·23	29·09	6·2
II	37·50	4·2	0·15	8·88	8·29	28·00	6·0
III	35·25	4·6	0·14	10·08	9·19	32·86	5·8

The first 6 in. of the profile have been impoverished of its finer mate presumably by erosion. In all other essential characters, these profiles re ble brown forest soils. The essential brown forest characters of the profil brought out more clearly from the clay analysis figures given in Table VI

TABLE VIII

Clay analysis and exchangeable bases of Doonagiri soils

(Pit No. 7)

Horizon	Per cent (air-dry basis)			$\frac{SiO_2}{R_2O_3}$	Exchangeable H (m.e. per cent on air-dry basis)	Per c base satu tio
	SiO_2	Al_2O_3	Fe_2O_3			
I	47·22	27·43	14·37	2·20	5·08	70·
II	45·16	28·03	15·17	2·03	4·35	72·9
III	44·90	28·43	14·77	2·01	7·25	59·2

Whereas the character and composition of exchangeable bases reser those of brown forest soils, a slight podsolic tendency is indicated by the d in SiO_2/R_2O_3 ratios.

Pit No. 6 : Khalkhet (Lower level of southern highlands)

Horizon	Depth	Description
I	0-6 in. . . .	Greyish brown ; loam containing undecomposed org matter ; more brown when wet
II	6 in.-1 ft. 5 in. .	Yellowish brown ; heavy loam ; more brown when
III	1 ft. 5 in.-2 ft. 6 in.	Reddish brown ; heavy loam ; deep red when wet

TABLE IX

Summarized analytical data on Doonagiri soils

(Pit No. 7)

Per cent (air-dry basis)					C/N	*p*H
Clay	Organic carbon	Total nitrogen	Fe_2O_3	Al_2O_3		
28·95	2·7	0·13	4·67	17·23	20·85	6·4
32·75	1·0	0·07	12·48	10·24	14·29	5·8
32·75	0·8	0·05	14·96	14·46	16·00	5·7

There is quite an appreciable eluviation of clay ; *p*H values and organic bon percentages resemble those of brown forest soils. We find, however, siderable translocation of ferric oxide, which, as is well known, is a podsolic racter.

The results of the clay analysis and data on exchangeable bases are sented in Table X.

TABLE X

Clay analysis and exchangeable bases of Doonagiri soils

(Pit No. 6)

Horizon	Per cent (air-dry basis)			$\frac{SiO_2}{R_2O_3}$	Exchangeable H (m.e. per cent on air-dry basis)	Per cent base-saturation
	SiO_2	Al_2O_3	Fe_2O_3			
I	44·04	26·83	16·77	1·99	8·70	55·84
II	44·60	24·03	15·97	2·21	1·45	87·50
III	40·62	21·34	20·76	1·99	1·45	89·10

The data given above leave no doubt as to the genetic nature of these ofiles. There is a very high eluviation of Fe_2O_3, specially from the first to third horizon. The base-exchange figures also indicate podsolic tendency the profile under reference. In view of the constancy of composition of O_2/R_2O_3 ratios this profile may be classified as brown forest soil with podsolic dency.

The general characters of all the five profiles discussed above show the stence of one genetic type of soil formation in this area. A casual observa-n, however, of the hill slopes in this area as well as over the whole of Kumaun

shows the presence of a large variety of soils with colours varying from d red to yellow. These soils are often shallow and occupy quite an appreci area of the Kumaun hills, and are utilized for the growing of grain cr or fruit trees. A number of profiles were examined in this area and such profile is described under and summarized analytical data are presen in Table XI.

Pit No. 1 : Kiyari (Western ridge)

Horizon	Depth	Description
I	0-1 ft. 6 in.	Yellowish brown ; loamy sand ; more br when wet and sticky. Some decompo platy phyllite rock present

TABLE XI

Summarized analytical data of Doonagiri soils

(Pit No. 1)

Per cent (air-dry basis)					C/N	*pH*
Clay	Organic carbon	Total nitrogen	Fe_2O_3	Al_2O_3		
16·45	0·86	0·03	8·70	20·50	28·66	5·

Absence of organic matter and therefore the seat of eluvial activity clearly indicated by both visual observations and by low contents of orga carbon and total nitrogen. The figure for the sesquioxides is comparativ higher and *p*H value much lower than what is usual for eluvial horizon in t locality.

Data on clay composition and exchangeable bases are given in Ta XII.

TABLE XII

Clay composition and exchangeable bases of Doonagiri soils

(Pit No. 1)

Per cent (air-dry basis)				Exchangeable H (m. e. per cent on air-dry basis)	Per cent base-saturation
SiO_2	Al_2O_3	Fe_2O_3	$\frac{SiO_2}{R_2O_3}$		
45·02	20·47	20·73	2·27	4·99	62·48

It is clear from the data presented in Tables XI a' ı XıI that the profile ıs some essential characters of lower horizons of pure brown forest soils dis- ıssed earlier in this section. The predisposing cause leading to the develop- ent of these soils is intense surface erosion in the past, but often such condi- ons are also brought about by faulty terracing practices. The soils because their acidic nature and peculiar dynamics should be classified as a variety brown forest soils resembling truncated forest soils of Sigmond's [1938] ain type 4 of soil order 10. Other profiles studied in this area have ıaracteristics similar to those described in these pages and can be classified to two major genetic groups, viz. brown forest soils and brown forest soils ith podsolic tendency.

Discussion

In the first two parts of this series of papers the possibility of classify- g hill soils according to their developmental characteristics has been clearly dicated. In the present instance the same method of soil classification has en followed. It has been possible by this method in the present case not nly to understand the characteristics of hill soils as a class but also the genesis the individual profiles. It is interesting to note that silica/sesquioxide ıtios of the clay fractions and per cent base-saturation figures taken together ıpply all the important data necessary for the classification and characteriza- on of soils in the hills. It is not implied by this that the organic matter con- nt, *p*H and mechanical composition do not offer any valuable assistance in ıe studies of hill soils, but that such determinations have limited importance consequence of the fact that they only confirm the findings arrived at from study of the clay composition and exchangeable bases.

Doonagiri soils belong to the usual brown forest soil type and on the ;erage these soils are very much richer in organic matter. Moreover, the ils of this locality contain a high proportion of plant nutrients. The largest ımber of successful fruit orchards of these hills are situated on soils formed om phyllite rock like that of Doonagiri, a fact that cannot be ascribed to ıance alone.

The prevalent colours of most of these soils at Doonagiri are black and ddish brown. Soils having the latter colour, as has been indicated above, long to truncated brown forest soil type. Soils having black colour are an ıportant study by themselves. It is not, as we find, that the higher content organic carbon always accounts for the black colour of the soil, but a high N ratio seems to have some direct bearing on the black colouration. Such ems to have been the case with pit No. 2. Soil containing 7·6 per cent of ganic carbon appears to be as organic as another soil which contains only 8 per cent organic carbon. Pit No. 3 also shows similar characteristics. rofile No. X15 Y15 [Mukerji and Das, 1941] is an analogous case.

The mean SiO_2/R_2O_3 ratio in the clay fractions of these profiles is $\cdot 15 \pm 0 \cdot 062$. This ratio is well within limits to be consistent with the pothesis that the primary weathering product of this locality is a mixture hydrated silicates having the general formula $R_2O_3 . 2\,SiO_2 . x\,H_2O$. Devia- ons from absolute value of 2 may have been brought about by eluviation ıd translocation. The usefulness of the silica/sesquioxide and silica/

alumina ratios for determining with certainty the genetic characteris... hill soils will be discussed more fully in the subsequent parts of this s... publications dealing with the developmental characters of soils d... ... other rock materials.

Summary

The nature of some soils formed at Doonagiri has been discussed.

Clay composition and per cent base-saturation taken together h... found very useful in characterizing these soils.

Silica/sesquioxide ratio has been found to be $2 \cdot 15 \pm 0 \cdot 24$ and, th... fore, the primary weathering product has been suggested to be a clay hav... the general composition $R_2O_3 . 2\ SiO_2 . x\ H_2O$.

The soils of the locality contain large proportions of organic matter, ... surface soils are on the whole highly base-saturated.

From the general study of the data it is evident that these soils b... brown forest soil group.

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STUDIES IN INDIAN RED SOILS

VI. DETERMINATION OF MINERALOGICAL COMPOSITION

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(With one text-figure)

THE usual method of characterizing soil types in the laboratory is to find out the physical and chemical composition of the soil samples, as well as of the clay fractions. These determinations, however, require long time to be carried out. Comparatively little attention has been paid, so far as the determination of the mineral compositions of soils, at any rate in India. The presence of great variety of minerals in soils was noted by McLaughey and Fry [1913], who reported the results of mineralogical studies of the chief soil groups of the United States. They identified optically 34 different minerals in a great variety of soils and concluded that the mineralogical composition of soils varies with the physiographic regions in which they occur. Among other workers who have discussed the constitution of soils from mineralogical standpoint are Delage and Lagatu [1904 ; 1905], Cayeau [1905], Hendrick and Newlands [1923; 1925 ; 1928], Hart [1935], Marshall [1935 ; 1936], Pearson and Truog [1937] and Bonnett [1939]. The determination of soil minerals is useful to the study of soils in two different ways :—

(1) In the first place, the content of minerals may indicate the nature of the parent material of the soil.

(2) In the second place, the determination of soil minerals may indicate the nature of inorganic soil colloids and of plant foods present in the soil. Moreover, permanence of fertility in a soil varies with its contents of minerals which are still liable to decomposition. A soil having a high content of such minerals is, other things being equal, better than a soil with no mineral reserves [Vageler, 1933].

In connection with his study on the nature of colloidal minerals of clay, Nagelschmidt [1939] has discussed all the important existing methods for determining the nature of clay minerals, viz. X-ray, optical, dehydration and chemical methods with special regard to their limitations. On the other hand, the importance of determining minerals of microscopic dimensions by the petrological methods has been pointed out by various workers (for a survey of literature see Harrison [1933]). In view of the scanty data on the mineralogical composition of Indian soils, it was felt desirable to determine the mineralogical composition of fine sand fractions of some typical profile

samples of red soils collected from different parts of India. The composition with respect to the rock-forming minerals of the soil is well represented by the fine sand fraction, except for minerals with flaky structure, such as mica, which tend to accumulate in the finer fractions. Volk [1933], in studying the formation of muscovite in soils, reports quantitative separation of mineral groups by means of liquids of different specific gravities. In recent papers, Truog and coworkers [1937-38] have sub-divided mineralogical constituents of soil by means of specific gravity separation with heavy liquid, such as tetra-bromo-ethane and nitro-benzene mixtures. Hendrick and Newlands [1923] have obtained good results on the separation of the heavy and light fractions of fine sand by bromoform (sp. gr. 2·9). Also by using a mixture of bromoform and benzene (sp. gr. 2·65), they separated quartz particles from the felspar grains, the sp. gr. of the quartz particles being higher than 2·65 (middle fraction), whilst that of the felspar particles being less (light fraction).

Experimental

The method of separation of the heavy, middle and light fractions of the fine sand, for the mineralogical and microscopical examination was essentially that described by Hendrick and Newlands [1923]. The work in the present paper can be divided into two sections. In the initial stages of the work (§I) the fine sand fractions with which the microscopical determinations were carried out, were not estimated quantitatively for the percentages of heavy, middle and light fractions. At this stage of the work, the heavy and light fractions were separated by shaking with bromoform (sp. gr. 2·9) only, but the separated fractions were not weighed. Also the nature of minerals on the microscopic slides were only qualitatively determined, but they were not counted for determining the percentages of different minerals in the slides.

In the second stage of the work (§II) it was felt desirable to obtain the mineralogical data of the soil samples on a quantitative basis. The fine sand fractions were accordingly separated into three fractions (heavy, middle and light) and their composition separately determined with the help of petrological microscope. The percentages of different minerals present in the slide were also carefully counted with the help of a graduated cross-wire eye-piece micrometer scale.

Separation of fine sand into heavy and light fractions

A special separating funnel illustrated in Fig. 1 was used to facilitate the work and minimize the chances of admixture of the separated minerals. The funnel is provided with a stopper closed at one end. The separated heavy mineral, therefore, collects in the opening so that by turning out the stopper the separation is complete. For actual experiment approximately 1·5-2 gm. of fine sand, after ignition, were treated with approximately 20 c.c. of $N/10$ oxalic acid and the mixture kept in contact for about 16 hours. By this treatment the grain were cleared of ferruginous matter. The supernatant liquid was then thrown out and the residue washed 10 times with distilled water by decantation in a beaker. The substance was then dried and an

curately weighed portion of it was treated with sufficient quantity of bromo-
rm in the special separating funnel described before. It was necessary
: the bromoform and the substance to remain in contact with each other
: a period of not less than three to four hours. The heavy fraction was
en isolated by turning out the stopper and was transferred to a dry filter
per, washed with benzene and dried (heavy fraction). The light fraction
hich was floating on the surface of the bromoform was then filtered through
dry filter paper, washed with benzene and dried. This dried substance
as subsequently treated in the same separating funnel with a mixture of
omoform and benzene of sp. gr. 2·62. The fraction which settled at the
ttom of the separating funnel and that which floated on the surface of the
quid were collected separately on dried filter papers, washed with benzene
d dried (middle and light fractions).

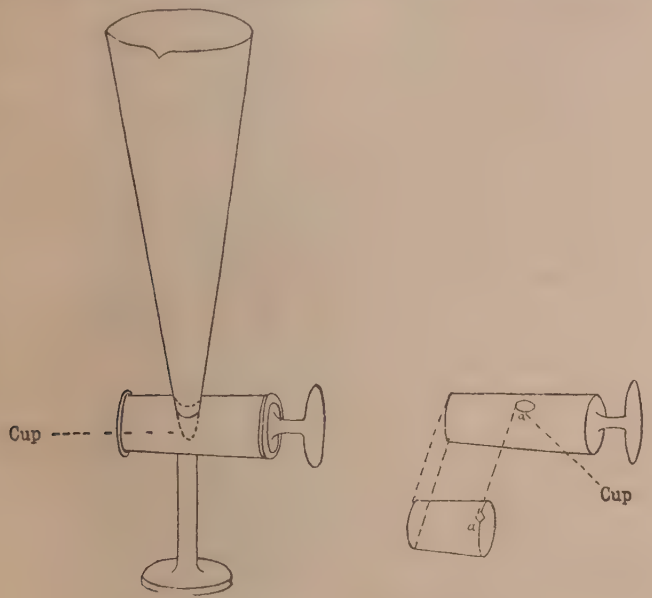

FIG. 1. Spaeth's separating apparatus

The sample and liquid are placed in the funnel and stirred. The heavy residue collects in a cup in the tap: the turning of the tap isolates the residue until the light minerals have been removed)

reparation of microscopic slides

The separated fine sand fractions were mounted on microscopic slides
ith Canada balsam by following essentially the procedure described by
ilner [1932].

§I. RESULTS AND DISCUSSION

The results have been summarized in Table I and, as far as possible, the
inerals have been written in descending order of abundance. It will be
und that iron ore minerals (e.g. limonite, magnetite, and haematite), as

also quartz and felspar grains, are uniformly present in high concentrations in all the profiles.

TABLE I

Soil minerals at different localities and the geological formations of those localities

Locality	Minerals	Parent materials*
Dacca Farm, Bengal	Iron ore minerals, quartz and felspar grains, epidote, hornblende, zircon and chloritic minerals	Old alluvium +?
Suri, Birbhum, Bengal	Iron ore minerals, quartz and felspar grains, epidote, zircon, garnet and chloritic minerals	Recent deposit +?
Bidar, Hyderabad	Iron ore minerals, quartz and felspar grains, garnet, chloritic minerals, epidote and biotites	Basalt +?
Himayethsagar, Hyderabad, Deccan	Iron ore minerals, quartz and felspar grains, hornblende, epidote, augite and chloritic minerals	Granite +?
Telankheri, Nagpur, C. P.	Iron ore minerals, quartz and felspar grains, epidote, zircon and chlorites and occasionally augites and hornblende. Also a few biotites	Basalt +?
Chandkhuri Farm, Raipur, C. P.	Iron ore minerals, quartz and felspar grains, garnet, zircon, chloritic minerals	Limestone +?
Alisagar, Hyderabad	Iron ore minerals, quartz and felspar grains, epidote, garnet, augites and a few chloritic minerals	Quartzite +?
Kakat, Cannanore, Malabar	Iron ore minerals, quartz and felspar grains, epidote, zircon, staurolite and chloritic minerals	Granite +?
Puzathi, Cannanore, Malabar	Iron ore minerals, quartz and felspar grains, epidote, augite, zircon and chlorites, occasionally tourmalines	Granite +?
Nilgiri Hills, Madras province	Iron ore minerals, quartz and felspar grains, epidote, augite, garnet, chlorite, zircon and biotite	Charnolite +?
Gorantla Hills, Guntur, Madras	Iron ore minerals, quartz and felspar grains, epidote, zircon, garnet, hornblende and a few staurolites	Granite +?
Stambhalaguruva, Guntur, Madras	Iron ore minerals, quartz and felspar grains, epidote, zircon, garnet, staurolites and chlorite, occasionally a few topaz	Granite +?
Khodappanam Kunnu, Trivandrum, Travancore	Iron ore minerals, quartz and felspar grains, epidote, zircon, garnet, chloritic minerals and a few muscovites	Gneiss +?
Government Fruit Farm, Cape Comorin	Iron ore minerals, quartz and felspar grains, epidote, hornblende, zircon, tourmaline and chloritic minerals	Gneiss +?

* It is likely that the exposed rocky pieces, which were collected from the places where the profiles were taken, constitute a part of the parent material. Hence the sign '?' has been added.

Many of the potash felspars of smaller sizes were turbid with decomposi- products (kaolinization). In almost all the soils the quartz particles characterized by rough angular appearance. Rounded grains are also times met with. Table I shows that the common ferro-magnesian rock- ing minerals are represented by one or more species in all the soils examin- one or other being present in preponderating amount. Hornblende present in some cases and that too in small amounts. Chlorite, an altera- product from the ferro-magnesians was found in most of the soils studied. ite was occasionally found (e.g. Nilgiri hills). These minerals are of tant nature and they are concentrated in material which has been sub- d to prolonged weathering and has accumulated from a variety of sources. ote and garnet were frequently found in granular form, whilst tourmaline especially zircon, though sometimes fragmentary, showed crystalline s.

Iron ore minerals like haematite, limonite and magnetite were present l the soils examined. With regard to the percentage of the ferro-silicate p of minerals in various soil samples, the soils of basic igneous origin found to be the richest. In almost all cases the proportion of resistant rals like epidote, garnet, zircon and tourmaline is higher compared with common rock-forming minerals like biotite and hornblende. The latter rals are the potential sources of plant food supply and these are usually nt in the soils in small amounts, which explains the comparatively little oductivity of these soil types. In a recent paper, Bonnett [1939] has rmined the mineralogical constituents of the silt fractions of samples a lateritic soil profile of Puerto Rico and has shown that the constituent rals are hydrated iron oxides, gibbsite, muscovite, secondary quartz serpentine. The accessory minerals, on the other hand, are : rutile, e, leucoxene, zircon, magnetite, chlorite, sericite, calcite, glass, ande- a kaolin-like mineral and traces of talc and epidote. The lateritic soils ndia studied differ from those of Puerto Rico in that they are mostly d to occur on quartzites and granitic rocks except in the case of central western and north-eastern parts of peninsular India, where the parent rial is basalt. The parent material of soil type of Puerto Rico is Andesitic The quartz particles found in such soil types seem to be mainly second- quartz.

The presence in almost all the soil types of a large proportion of iron es and highly resistant unweathered minerals such as epidote, zircon, naline, etc. suggests that the soil has been formed of prolonged chemical n which took place prior to present soil-forming processes. The alter- e suggestion is that these soils have been subjected to extensive erosion minerals of comparatively low specific gravity have been washed down ng behind minerals of comparatively high specific gravity like epidote, n, tourmaline, etc.

§ II. Mechanical analyses of soil samples

The mechanical analyses were carried out by following essentially the edure developed by Robinson [1933]. The data on the percentages of se sand, fine sand, silt and clay are shown in Table II.

Table II

Mechanical composition of soil samples

(Air-dry basis)

Locality	Sample No.	Depth	Coarse sand (per cent)	Fine sand (per cent)	Silt (per cent)	Cl (per c
Hathwara, Manbhum, Bihar	81p	0—1 ft. 6 in.	38·0	21·0	9·0	30·
	82p	1 ft. 6 in.—2 ft. 3 in.	41·0	17·5	10·8	28·
	83p	2 ft. 3 in.—3 ft. 6 in.	34·9	21·6	10·8	31·
	84p	3 ft. 6 in.—4 ft. 11 in.	34·9	11·8	15·9	33·
	85p	Below 4 ft. 11 in.	40·0	20·0	11·2	28·
	86p	Below 30 ft.	61·6	17·1	5·5	14·
Putida, Singhbhum, Bihar	87p	0—1 ft.	22·7	21·5	17·2	37·
	88p	1 ft.—2 ft. 9 in.	30·9	12·0	13·2	37·
	89p	2 ft. 9 in.—4 ft.	48·8	15·5	10·4	19·
Ratu, Ranchi, Bihar	90p	0—1 ft.	23·8	19·6	14·9	37·
	91p	1 ft.—2 ft.	17·9	14·5	15·4	48·
	92p	2 ft.—3 ft.	26·0	13·0	13·2	44·
	93p	3 ft.—4 ft.	31·3	11·3	9·1	45·
Baralota, Daltonganj, Bihar	94p	0—1 ft. 11 in.	21·4	32·6	16·0	28·
	95p	1 ft. 11 in.—2 ft. 9 in.	15·7	21·1	13·8	44·
	96p	2 ft. 9 in.—4 ft.	16·9	16·0	12·6	49·
	97p	4 ft.—5 ft.	48·8	17·1	19·6	12·
Tangi, Cuttuck, Orissa	98p	0—1 ft.	35·0	33·8	14·8	14·
	99p	1 ft.—2 ft.	32·1	27·9	17·0	20·
	100p	2 ft.—4 ft.	49·1	20·1	9·1	17·
Dhanmandal, Cuttuck, Orissa	101p	0—5 in.	28·7	23·8	14·6	31·0
	102p	5 in.—4 ft.	16·0	9·0	7·5	61·
Kapileswar, Bhubaneswar, Orissa	103p	0—2 ft. 11 in.	40·1	21·0	11·6	26·4
	104p	2 ft. 11 in.—4 ft.	49·0	19·4	3·1	27·6
	105p	Below 30 ft.	41·3	15·7	12·6	28·0
Jhinkartangi, Khurda Town, Orissa	106p	0—1 ft.	34·3	10·2	12·2	39·4
	107p	1 ft.—2 ft.	22·1	11·0	13·4	48·9
	108p	2 ft.—8 ft. 6 in.	44·7	11·7	11·7	28·3
	109p	8 ft. 6 in.—10 ft.	42·5	24·9	6·7	22·4
	110p	30 ft.—50 ft.	29·9	20·5	19·0	29·3
Lalgarh, Midnapur, Bengal	112p	0—4 in.	28·3	18·8	10·4	39·
	113p	4 in.—3 ft. 4 in.	40·0	18·5	2·8	35·2
	114p	3 ft. 4 in.—4 ft.	46·6	18·2	7·6	26·7
	115p	7 ft.—8 ft.	13·4	41·5	6·6	34·2
Mailda, Midnapur, Bengal	116p	0—8 in.	39·3	44·7	4·4	9·5
	117p	Bed soil of Cossye R.	5·0	19·3	24·3	44·0
	118p	40 ft. below	39·5	13·4	13·2	32·8

TABLE II—*contd.*

Locality	Sample No.	Depth	Coarse sand (per cent)	Fine sand (per cent)	Silt (per cent)	Clay (per cent)
hlang, Khasi Hills, am	119p	0—6 in. . . .	17·9	12·0	23·7	37·0
	120p	6 in.—1 ft. 3 in. .	20·5	11·3	23·3	35·6
	121p	1 ft. 3 in.—2 ft. 1 in. .	18·6	11·7	23·3	38·6
	122p	2 ft. 1 in.—4 ft. .	25·0	9·5	23·4	35·4
: Chandmari, Tura, o Hills, Assam	144p	0—3 in. . . .	43·5	18·4	14·7	20·2
	145p	3 in.—1 ft. 8 in. .	54·6	18·6	10·5	15·0
	146p	1 ft. 8 in.—2 ft. 8 in.	65·2	16·4	8·4	9·1
	147p	2 ft. 8 in.—4 ft. .	63·7	12·9	13·8	8·1

The mechanical analyses data show generally a more sandy texture the surface soil than for the subsoil. This fact has been usually ascribed andy wash of external origin, or to mechanical eluviation within the ile. Robinson [1936] has suggested a third possibility in that it might lue to normal erosion, as distinct from catastrophic erosion, involving ral movement of the finer fractions. Such removal, according to him, ht take place along the surface of the soil itself or along the surface of a er-table and, in either case, the result would be to produce a surface horizon tively richer in the coarser fractions than the parent material.

*mation of minerals of different grades in the fine sand fraction**

The fine sand fractions were treated with oxalic acid to remove the cement-iron oxide material, washed, dried and then separated into three fractions, etailed below, by shaking with bromoform (sp. gr. 2·9) and a mixture of noform and benzene (sp. gr. 2·62) :—

(*a*) Sp. gr. higher than 2·9, mostly ferro-magnesian minerals
(*b*) Sp. gr. between 2·62 and 2·9, mostly quartz grains
(*c*) Sp. gr. less than 2·62, mostly felspar grains

these three fractions were washed, dried and separately weighed in che-al balances. This gave the percentages of different fractions in the fine l.

Table III shows the quantities of different fractions expressed as per-age of fine sand and of the soils.

The results show that the soils of Midnapur, Bengal, are the richest he percentages of heavy minerals. The soils of Palamau (Daltonganj), uttuck (Orissa), and of Puri (Orissa) are intermediate in their content of vy minerals. The greater the percentages of heavy minerals present in soil, the greater would be the probability that the soil is changing into ew one provided external disturbing factors like erosion be not present. se considerations, however, do not apply to the case when resistant mine-like garnet or iron oxide are present. On the basis of these general con-rations we should expect that the soils obtained from Khasi hills, Assam, lso from the districts of Manbhum and Singhbhum have been weathered great extent, whilst the soil of Midnapur are comparatively immature.

*The silt fraction was not analysed quantitatively, because it was not found practi-e to utilize the heavy liquid method of separation for material of so fine a grade.

The percentages of the middle and light fractions in the soil types do yield any useful information unless the percentages of minerals contain useful plant nutrients be separately determined.

TABLE III

Different fractions expressed as percentage of fine sand and of soil

Locality	Soil No.	Heavy fraction		Middle fraction		Light fraction		Error as per cent of fine sand
		Fine sand (per cent)	Soil (per cent)	Fine sand (per cent)	Soil (per cent)	Fine sand (per cent)	Soil (per cent)	
Hathwara Farm, Manbhum, Bihar	81p	1·2	0·252	2·1	0·440	90·4	19·0	6
	82p	1·8	0·315	1·7	0·298	88·4	15·5	8
	83p	2·2	0·475	2·2	0·475	88·4	19·1	7
	84p	2·2	0·26	2·4	0·284	85·2	10·1	10
	85p	0·5	0·1	3·3	0·66	89·2	17·84	7
	86p	7·8	1·37	37·9	6·5	48·8	8·35	5
Putida, Singhbhum, Bihar	87p	1·3	0·279	70·2	15·1	16·7	3·59	11
	88p	0·8	0·096	45·9	5·51	47·8	5·73	5
	89p	0·3	0·0465	60·2	9·33	32·6	5·05	6
Ratu, Ranchi, Bihar	90p	5·9	1·16	68·0	13·3	17·4	3·4	8
	91p	3·7	0·536	40·4	5·86	47·2	6·84	8
	92p	5·2	0·676	13·4	1·74	70·7	9·19	10
	93p	6·8	0·768	44·8	5·06	43·2	4·88	5
Daltonganj, Palamau, Bihar	94p	9·9	3·23	7·3	2·38	76·6	24·9	6
	95p	4·7	0·992	6·6	1·39	82·5	17·4	6
	96p	5·5	0·88	15·4	2·47	72·6	11·6	6
	97p	0·3	0·513	1·3	0·222	95·5	16·3	2
Tangi, Cuttuck, Orissa	98p	7·0	0·237	6·1	2·06	83·9	28·4	3
	99p	7·5	0·209	7·7	2·15	79·8	22·3	5
	100p	30·7	6·07	31·3	6·29	34·1	6·85	3
Dhanmandal, Cuttuck, Orissa	101p	7·6	1·81	11·9	2·83	76·7	18·3	3
	102p	10·8	0·972	7·1	0·639	77·4	6·66	4
Kapileswar, Bhubaneswar, Orissa	103p	9·2	1·93	37·7	7·91	49·2	10·3	3
	104p	12·8	2·48	33·9	6·58	51·5	10·0	1
	105p	5·4	0·848	14·9	2·33	77·6	12·2	2
Jhinkartangi, Khurda, Puri, Orissa	106p	9·3	0·948	32·6	3·33	54·1	5·52	4
	107p	12·8	1·41	36·2	3·98	44·8	4·94	6
	108p	16·3	1·91	20·6	3·04	58·2	6·81	4
	109p	25·1	6·24	45·2	11·25	26·5	6·60	3
	110p	2·4	4·92	19·6	4·90	74·6	15·3	3
Lalgarh, Midnapur, Bengal	112p	2·9	5·45	1·9	0·357	92·6	17·4	2
	113p	2·1	3·89	8·2	1·52	87·1	16·1	2
	114p	1·2	2·18	0·7	0·1274	96·5	17·6	1
	115p	0·9	0·374	0·8	0·332	95·6	39·7	2
Mailda, Midnapur, Bengal	116p	2·1	9·38	5·2	2·32	91·1	40·7	1
	117p	0·9	0·174	40·8	7·37	54·8	10·6	3
	118p	1·2	0·161	42·4	5·68	53·97	7·22	2

* Represents loss of material in working manipulation

TABLE III—*contd.*

Locality	Soil No.	Heavy fraction		Middle fraction		Light fraction		Error* as per cent of fine sand
		Fine sand (per cent)	Soil (per cent)	Fine sand (per cent)	Soil (per cent)	Fine sand (per cent)	Soil (per cent)	
	119p	0·6	0·072	24·5	2·94	68·9	8·26	6·0
phlang, Khasi lls, Assam	120p	0·6	0·0678	13·9	1·57	78·5	8·87	7·0
	121p	0·8	0·0936	6·0	0·72	86·9	10·17	6·3
	122p	0·5	0·0475	3·7	0·352	86·7	8·24	9·1
	144p	11·9	2·19			87·4	16·1	0·7
ro Hills, Upper andmari, Tura	145p	5·8	1·08			93·2	17·3	1·0
	146p	6·6	1·08			92·0	15·1	1·4
	147p	5·80	0·75			93·1	12·0	1·1

*Represents loss of material in working manipulation
In the case of these soils the data in the column of light fraction represent both the light and middle fraction

It seems on the whole that the soils generally are fairly rich in their spar constituents. The proportions of the middle fraction which consist inly of quartz particles are, however, not so high except in a few cases (e.g. gbhum, Ranchi and Midnapur).

imation of minerals in the heavy fraction of the fine sand

The separated fine sand fractions were mounted on microscopic slides h Canada balsam by following essentially the procedure described by ner [1932]. It was found that the nature of the minerals in the middle d in the light fractions of all the soil samples were very nearly the same. e mineralogical composition of these fractions was generally as follows : inly quartz and felspar grains and some kaolinized felspars ; most of the artz and felspar grains were found to be stained with limonitic materials ; oritic minerals were also found.

Detailed quantitative mineralogical studies were undertaken with the avy fractions only.

termination of different minerals in the heavy fractions

A square-type graduated micrometer scale was used inside the micros- pe eye-piece. The microscope tube was adjusted so that the micrometer le was in the field of view along with the minerals of the microscopic slide d the total number of minerals in the graduated square area were counted. e number of individual minerals in the same area were also determined. simple process of calculation the percentages by volume of the various nerals in the microscopic slide could be calculated and multiplying these lume percentages by the specific gravity of the minerals, the percentages by ight of the minerals can be obtained. It is, however, necessary to take arge number of counts in order that the calculated percentages by weight the minerals might be approximately correct. If a large number of counts e taken, it is found that the percentages of the various minerals agree thin 10 per cent.

Table IV gives in one place the data on the percentages by weight of rious minerals in the heavy fraction of the fine sand along with the nature the parent materials of the soil types.

TA

Weight of minerals in

Locality	Soil No.	Depth	Iron oxide**	Zircon	Epidote	Horn-blende	Tour-malin
Hathwara, Manbhum, Bihar	81p	0—1 ft. 6 in.	67·5	109·0	24·2	35·3	
	82p	1 ft. 6 in.—2 ft. 3 in.	85·5	171·0	19·7	34·8	
	83p	2 ft. 3 in.—3 ft. 6 in.	147·0	232·0	36·0	40·5	5
	84p	3 ft. 6 in.—4 ft. 11 in.	79·5	108·0	22·2	15·7	7
	85p	Below 4 ft. 11 in.	35·5	36·2	13·4	8·85	1
	86p	Below 30 ft.	93·5	1150·0	23·5		
Putida, Singhbhum, Bihar	87p	0—1 ft.			74·0	5·44	
	88p	1 ft.—2 ft. 9 in.	4·34	4·2	3·11		
	89p	2 ft. 9 in.—4 ft.	2·59		0·77		
Ratu, Ranchi, Bihar	90p	0—1 ft.	1050	27·6	30·6	54·0	
	91p	1 ft.—2 ft.	460	5·36	22·3		8
	92p	2 ft.—3 ft.	624	8·12	24·0	21·2	
	93p	3 ft.—4 ft.	715	9·24	13·7	24·1	6
Baralota, Daltonganj, Bihar	94p	0—1 ft. 11 in.	514			2540·0	36
	95p	1 ft. 11 in.—2 ft. 9 in.	302		6·75	675·0	
	96p	2 ft. 9 in.—4 ft.	239			573·0	
	97p	4 ft.—5 ft.	134	217·0		84·6	
Tangi, Cuttack, Orissa	98p	0—1 ft.	30·6		88·5		
	99p	1 ft.—2 ft.	25·1		86·0		
	100p	2 ft.—4 ft.	16·6		39·8		
Dhanmandal, Cuttack, Orissa	101p	0—5 in.	437		360		
	102p	5 in.—4 ft.	333		204		
Kapileswar, Bhubaneswar, Orissa	103p	0—2 ft. 11 in.	1800	47·5	35·1		
	104p	2 ft. 11 in.—4 ft.	2400		44·8		
	105p	Below 30 ft.	675		71·5		
Jhinkartangi, Khurda town, Orissa	106p	0—1 ft.	687	180	66·5		
	107p	1 ft.—2 ft.	935	407	60·2		
	108p	2 ft.—8 ft. 6 in.	1220	494	83·0		
	109p	8 ft. 6 in.—10 ft.	4330	1270	111·0		
	110p	30 ft.—50 ft.	4120	415	307·0		
Lalgarh, Midnapore, Bengal	112p	0—4 in.	4000	205	353		578
	113p	4 in.—3 ft. 4 in.	3090	96	71	62·6	282
	114p	3 ft. 4 in.—4 ft.	1470	162	120		211
	115p	7 ft.—8 ft.	273	18·7	24·1		36·6
Mailda, Midnapore, Bengal	116p	0—8 in.	6030	463·0	770·0	453	906·0
	117p	Bed soil of Cossye R.	199·5	8·75	14·5		19·9
	118p	48 ft. below	112·0	8·30	16·9		18·9
Mawphlang, Khasi Hills, Assam	119p	0—6 in.	53·8	2·71	9·35		1·
	120p	6 in.—1 ft. 3 in.	49·4	4·98	7·38		1·0
	121p	1 ft. 3 in.—2 ft. 1 in.	62·0	4·88	12·30		3·1
	122p	2 ft. 1 in.—4 ft.	31·4	2·38	4·40		3·8
Upper Chandmari, Tura, Garo Hills, Assam	144p	0—3 in.	1930	184·0	77·5		
	145p	3 in.—1 ft. 8 in.	900	104·0	76·7		
	146p	1 ft. 8 in.—2 ft. 8 in.	925	104·0	1·93		
	147p	2 ft. 8 in.—4 ft.	643	10·6			

*Calculated from the percentages of heav

** These represent resistant forms of oxides of iron whi

*r 10^5 gm. of soil**

auro-ite	Garnet	Augite	Chlo-rite	Cal-cite	Dolo-mite	Rutile	Bio-tite	Kya-nite	Parent material
	4·5	8·05	3·29						Granite and syenite
	2·76		2·02						
	6·41	7·65	4·68						
	4·95	8·88	1·45						
		3·34	1·37						
							75·7		Do.
						72·5		126·5	Dalma traps and Mergui volcanics
						843·0			
						414·0		1·7	
13·2									Unclassified crystalline gneiss, etc.
	23·3	41·7	50·9			19·0			
	7·54		13·1			6·15			Limestone, shales and slates
	13·7	12·2	25·0			16·7			
	72·0							5·89	
						118			Older alluvium and laterite
						98			
						545			
						1020			Laterite mixed with granite and sandstone
						435			
		23·8	78·0					44·0	Gniess
								28·1	Do.
					14·0				Do.
	6·74								
					69·8	41·4			
			45·3	88·5	329·0	69·0			
					74·0				Do.
74					42·6				Older alluvium and laterite
54					89·7	44·2			
52					32·8	24·9			Do.
15·0			2·82		2·91				
58·0		1·61	140·0		72·2				Older alluvium and laterite
3·52			1·32		2·72		1·47		Do.
5·0					1·30	3·83			Do.
			1·63		1·69	0·83			
			2·01			3·06			Shillong series
			7·90		1·48	2·19			
			0·72		1·49	3 29			
			3·16						Pab-sandstone

neral in the soil (Table III)

uld not be removed by treatment with oxalic acid

On the basis of the data given in Table IV, the soil profiles studied ma be tentatively grouped as follows :—

1. Zircon preponderant . .	(*a*) Hathwara Farm (Purulia, Bihar)
	(*b*) Jhinkartangi (Khurda Town, Orissa)
	(*c*) Upper Chandmari (Tura, Garo Hills, Assam
2. Hornblende preponderant .	Baralota (Daltonganj, Bihar)
3. Rutile preponderant . .	(*a*) Putida (Singhbhum, Bihar)
	(*b*) Tangi (Cuttack, Orissa)
	(*c*) Dhanmandal (Cuttack, Orissa)
4. Epidote preponderant .	(*a*) Tangi (Cuttack, Orissa)
	(*b*) Dhanmandal (Cuttack, Orissa)
	(*c*) Mawphlang (Khasi Hills, Assam)
5. Tourmaline preponderant .	Midnapore (Bengal).

Mention may be made here of the work of Jeffries [1937], who working with some Pennsylvania soils, has concluded that the percentages of mineral present in the soils can be used as an important aid in soil classification.

Summary and conclusions

The present work was undertaken with a view to characterizing some profiles of red and lateritic soils collected from different parts of India by finding out the mineralogical composition of the fine sand fractions of the profile samples, and from the mechanical composition of the soils and the chemical composition of the clay fractions.

In the initial stages of the mineralogical work, the fine sand fractions with which the microscopic determinations were carried out, have not been estimated quantitatively for the percentages of heavy, middle and light fractions. At this stage of the work the heavy and light fractions were separated by shaking with bromoform (sp. gr. 2·9) only, but the separated portions were not weighed. Also the nature of the minerals on the microscopic slides was only qualitatively determined, but they were not counted for determining the percentages of different minerals in the slides.

In the later stage of the microscopical work it was felt desirable to obtain the mineralogical data of the fine sand fractions on a quantitative basis. The fine sand fractions were accordingly separated into three fractions, viz. heavy (sp. gr. 2·9), middle (sp. gr. 2·9-2·65), and light (sp. gr. 2·65) which were weighed separately and their mineralogical compositions determined with the help of a petrological microscope. The percentages of different minerals present in the heavy fractions were also carefully counted with the help of a graduated cross-wire eye-piece micrometer scale.

Common ferro-magnesian rock-forming minerals are represented by one or more species in all the soils examined, one or the other being present in preponderating amount. Hornblende was occasionally present. Chlorite was found in most of the soils studies. Biotite was occasionally found (e.g. Nilgiri hills). These minerals are of resistant nature and they are concentrated in material which has been subjected to prolonged weathering and has accumulated from a variety of sources. Epidote and garnet were frequently found in granular form, whilst tourmaline and especially zircon, though sometimes fragmentary, showed crystalline forms.

Iron minerals like haematite, magnetite and limonite were present in all the soils examined.

With regard to the percentage of the ferro-silicate group of minerals, the soils of basic igneous origin are naturally the richest.

In almost all the cases the proportion of rarer accessory minerals like ote, zircon, garnet and tourmaline is higher compared with the common -forming minerals like biotite and hornblende. The latter minerals are potential sources of plant food supply and are usually present in the soil ples in small amounts, which explains the comparatively little unproducti- of the soil types.

The general nature and proportions of minerals in the light (sp. gr. less 2·65) and middle fractions (sp. gr. between 2·9 and 2·65) of all soil ples were found to be very similar. In the light fraction the assemblage inerals consisted mostly of felspar and grains of quartz often stained with es of iron. In the middle fraction, on the other hand, the predominating erals were quartz grains, mixed with some felspars, both being stained with e of iron.

The outstanding minerals present in the heavy fraction are iron oxide, on, tourmaline, staurolite, chlorite, hornblende, epidote and rutile. In w cases, the existence of minerals like leucoxene, augite, dolomite, cal- and biotite were noticeable.

On the basis of the percentages of the mineralogical constituents in the ile samples, the soil profiles have been tentatively grouped into five classes.

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DETERMINATION OF ORGANIC PHOSPHORUS IN ALKALI EXTRACTS OF SOILS

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DEAN [1938] outlined a colorimetric method for determining inorganic organic phsophorus in the alkali extracts of soils. The colour of the tract was removed either by using kiesselguhr as an absorbent or by oxidiz it by means of sodium hypobromite at 95°—100° C. The amount of ph phorus determined colorimetrically on the decolourized extract was assur to be inorganic and the difference of the inorganic phosphorus thus determi and the total phosphorus to the extract determined separately by ashing taken to represent the organic phosphorus fraction of the extract. principle underlying this separation is that the organic phospho compounds do not liberate any free phosphate ion by the decolourizing tre ments. The high temperature at which bromine oxidation was carried by Dean suggests the possibility of some organic phosphorus being decompo into inorganic form in which case the separation would become absolut untrustworthy. Moreover, to get reproducible results it is essentially ne sary that the conditions of bromine oxidation should be clearly specified. work was undertaken with a view to examining the conditions of brom oxidation, in obtaining a method which would allow the organic colou matter to be removed without destroying any organic phosphorus compou For this purpose the alkali extracts of five soils (A. E. A. samples) were colourized by various treatments as shown below.

Decolourizing treatments

(1) Bromine oxidation at boiling temperature, excess bromine be boiled off after acidification (Dean's procedure).

An aliquot of the alkali extract was treated with 5 c.c. of bromine wa and heated on a water bath until decolourization was complete. The extr was then acidified to liberate the excess bromine. The bromine was fina boiled off on a water bath until the extract was colourless.

(2) Bromine oxidation at 40°C., excess bromine being boiled off.

The brominated extract was heated on a water bath which was kept 40°C. The excess bromine was boiled off as in (1).

(3) Bromine oxidation at 40°C., excess bromine being removed at 40°C

The bromine oxidation was done at 40°C. as in (2). The extract v acidified as before and then heated on a water bath kept at about 40°C. u all the bromine was driven off.

(4) Bromine oxidation at room temperature, excess bromine being moved by aeration.

Bromine water was added to the extract and the extract allowed to stand for some time. It was then acidified as before and a current of air bubbled through it until it was colourless.

(5) Kiesselguhr method (Dean's procedure)—An aliquot of the extract was acidified and heated. The coagulated humus was filtered off and the filtrate shaken with kiesselguhr and again filtered.

(6) Kiesselguhr method (modified)—The humus was coagulated as in (5) but not filtered off before shaking with kiesselguhr.

The inorganic phosphorus was determined in the colourless extract after decolourization had been effected by the above treatments. The total phosphorus of the original alkali extract was estimated by ashing (as shown later) and the organic phosphorus was obtained by difference. The colorimetric method of Deniges [1920] as improved by Truog and Meyer [1929] was used all through. The results showing the organic phosphorus figures only are given in Table I.

TABLE I

Effect of bromine oxidation at different temperatures on the organic phosphorus in the alkali extract

(Organic P_2O_5 in mg. per 100 gm. of soil)

Soil	A 1441 Broadbalk head land, heavy loam, acid	A 1442 Woburn, sandy loam, acid	A 1443 Bangor, loam, neutral	A 3328 Carbello, loam, acid	A 2865 King's lynn, sandy loam, alkaline
Treatments					
1. Oxidation and expulsion of bromine at 100°C.	46	24	132	45	23
2. Oxidation at 40°C. and expulsion at 100°C.	48	..	130	..	..
3. Oxidation and expulsion at 40°C.	62	32	156	52	32
4. Oxidation and expulsion at room temperature	64	33	160	56	32
5. Kiesselguhr (Dean's) .	64	33	160	56	35
6. Kiesselguhr (modified) .	65	33	160	56	33
Total P_2O_5 extracted by alkali	126	74	320	96	72

It will be seen from the table that the temperature of bromine oxidation has a great deal of effect on the organic phosphorus determined. If both

bromination and expulsion of excess bromine are carried out at 100°C. as in (1), the organic phosphorus figures are much lower as compared with the figures obtained by the Kiesselguhr method which shows that at this high temperature the organic phosphorus compounds are considerably, broken down by bromine, to be determined as inorganic phosphorus. It has, of course, been assumed that no such transformation takes place by the treatment with kiesselguhr. When both the operations are carried out at 40°C. as in (3), the results are comparable with those of the Kiesselguhr method. But again if only the expulsion is done at 100°C. as in (2), the figures fall down to the original values as obtained in (1), from which it becomes evident that neither the bromine oxidation nor the expulsion of the excess bromine can be undertaken at 100°C. without affecting the organic phosphorus fraction. Though the results are not affected by the treatments in (3), the removal of excess bromine at 40°C. was found to take more than 2½ hours. Bromination at room temperature and removal of excess bromine by aeration as in (4) compare very favourably with the kiesselguhr and the low temperature oxidation methods. The cold bromination also simplifies the procedure to a great extent, the reaction is completed in a few minutes and the excess bromine can also be removed in a short time. This, therefore, affords a simple and efficient means for the separation of the inorganic and organic phosphorus in the alkali extracts of soils.

As regards the kiesselguhr method it will be seen that the procedure can be a little simplified as in (6) without affecting the results. This method is not only long and tedious but is also incapable of general application. Kiesselguhr can be used as a decolourizing agent only in the case of lightly coloured extracts. Experience showed that even moderately coloured extracts could not be decolourized by it.

Subsequent experience with a large number of determinations on a variety of soils showed that the cold bromination method can be applied successfully to all soils. An occasional highly organic soil may require large amounts of bromine water. While working with some black fen soils giving highly coloured alkali extracts, the author had the opportunity to compare again the original method of Dean with the method proposed by him. Table II contains the results of organic phosphorus determination by the two methods in three successive alkali extracts of two fen soils. Kiesselguhr method was completely ineffective in these cases.

The proposed method gives higher values of organic phosphorus in all the extracts of the two soils. This conclusively shows that the organic phosphorus compounds are considerably decomposed during the process of bromine oxidation at 100°C. as originally proposed by Dean. This breakdown is not, however, proportional to the total organic phosphorus in the extract. It probably depends upon the nature and kind of organic phosphorus compounds and therefore varies from soil to soil. It will be noted that in the second extract of soil A 3560-1 the whole of the organic phosphorus was broken down.

The method finally proposed for the determination of inorganic and organic phosphorus in the alkali extracts of soils may be stated as follows :—

An aliquot of the alkali extract (however obtained) is measured into a 100 c.c. conical flask and treated with a saturated solution of bromine in water,

ie volume of bromine required varying from 2 to 15 c.c. according to the olour of the extract. When a large amount of bromine is used, an equivalent mount of alkali should be added if the extract is not sufficiently alkaline already. The brominated extract is allowed to stand for a quarter of an hour ed is then acidified with 6N sulphuric acid until bromine is liberated. The ask is then connected to a filter pump and a current of air is bubbled through remove free bromine. When the extract is colourless it is washed into a easuring flask (50 or 100 c.c.), made up to volume, filtered and the phosphorus etermined colorimetrically on an aliquot.

TABLE II

Comparison of the original method of Dean and the proposed method of determining the organic phosphorus in alkali extracts

(Organic P_2O_5 expressed as mg. per 100 gm. of soil)

Soil	Method	1st extract	2nd extract	3rd extract	Total
3560-1 Littleport, heavy entral fen	Original method	25·0	0·0	4·0	29·0
	Proposed method	54·0	17·0	5·2	76·2
3246-47 Peterboro, heavy acid fen	Original method	55·0	10·0	5·8	70·8
	Proposed method	80·0	17·0	8·7	105·7

The total alkali soluble phosphorus is determined on an aliquot which is evaporated to dryness with 2 c.c. of 10 per cent solution of magnesium nitrate in a porcelain basin and gently ignited. The ignited residue is treated with 1 c.c. of conc. hydrochloric acid, the basin being covered with a watch glass. It is then diluted with water to about 20 c.c. and heated on a sand-bath for 15 minutes. The extract is made to a known volume and phosphorus determined on an aliquot. The organic phosphorus is obtained by difference.

SUMMARY

1. The colorimetric method for the estimation of inorganic and organic phosphorus in alkali extracts of soils as proposed by Dean has been critically examined.

2. It has been found that the bromine oxidation at 100°C. breaks down a part of the organic phosphorus compounds.

3. On the other hand, the oxidation at room temperature does not decompose any organic phosphorus.

4. A simplified procedure for the separation of organic and inorganic phosphorus in the alkali extracts of soils by bromine has been described.

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SEEDLING-ADULT COLOUR RELATIONSHIPS AND INHERITANCE IN SORGHUM

BY

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(With Plate IX)

PLANT pigments can be classified broadly into two groups, the vegetative and the ornamental. The vegetative pigments are those that are related to the chlorophyll and are therefore indispensable for the normal metabolic activities of the plant. The ornamental pigments have a comparatively less important rôle and though several functions of a physiological and biological nature are attributed to them, they do not seem to be vital to plant life. Sorghum seedlings manifest various types of pigmentation soon after they emerge from the soil and after a few days of growth. Several colour patterns that are associated with chlorophyll exist in sorghum. Under the term 'seedling colours' referred to in this paper are included the colours other than those that are related to chlorophyll. These are confined either to the cell-sap or to the cell-wall and do not exist in the plastid condition like those of the chlorophyll group.

Attempts to classify the sorghum seedlings into pigmentation types have been made in the past. Reed [1930] classified them into two groups, those with red-coloured coleoptiles and those with green coleoptiles. The seedlings with red coleoptiles proved a simple dominant to those with green coleoptiles. Rangaswami Ayyangar [1930, 1932] recorded a simple monogenic segregation between purple and green seedlings. Rangaswami Ayyangar [1934], Rangaswami Ayyangar, Ponnayya and Reddy [1938] refer to the segregation of purple and green coleoptiles. Karper and Conner [1931] made mention of red-stemmed seedlings which behaved as a simple dominant to non-red stemmed seeedlings. Fevorow and Havenselman [1934], investigating the hybrids of sorghum and sudan grass, mentioned that the violet colour of the shoot of sudan grass is due to the presence of one dominant factor. Woodworth [1936] reported a 9 : 7 segregation between red-stemmed and green-stemmed seedlings in a cross between Shallu and Black Spanish : Rangaswami Ayyangar, Rao and Reddy [1938] have reported a simple segregation of deep purple and purple plumules close on emergence from the soil. The deep purple pigment of the plumules always went with the purple colour of the anthers.

This pigmentation in sorghum seedlings was made use of by plant breeders in several instances. It is an old observation at the Millets Breeding Station,

Coimbatore (south India), that in pure breeding lines of sorghum, odd seedlings possessing a different seedling colour from the type occur very often. These seedlings later on prove to be the resultants of natural crossing. If allowed to grow to maturity they contaminate the inbreeding line still further since sorghum is easily susceptible to cross-pollination and up to as much as 50 per cent of natural crossing is reported in adjacent rows [Ball, 1910]. Hence these seedlings are pulled out in order to prevent further contamination of the inbreeding line. Reed [1930] was able to detect sorghum hybrids at the seedling stage itself with the help of the dominant seedling colour. He selected a parent possessing the recessive seedling colour as mother and pollinated it with a male parent having the dominant seedling colour. The mother parent was not emasculated before pollination. When the seeds of this parent were sown, both the mother type and hybrid seedlings were produced. The hybrid seedlings were readily distinguished from the mother type by the help of the dominant seedling colour which they possessed. Rangaswami Ayyangar [1930] made use of the segregation of purple and green seedlings for demonstrating a simple mendelian segregation graphically by germinating and growing the seedlings on the earhead itself. Vinall, Stephens and Martin [1936] distinguished red and green coleoptiles and made use of this colour for the classification and identification of sorghum varieties of the United States of America.

During the years 1930-36, a large number of sorghum varieties from several important sorghum centres of the world were obtained and grown at the Millets Breeding Station, Coimbatore. Among these, many varieties, especially those from Africa, exhibited certain types of seedling colours which have not so far been recorded. In a previous paper [Rangaswami Ayyangar, 1934] mention has been made of sorghum seedlings with coloured and colourless roots. This aspect was explored and elaborated further; this has led to the knowledge of the existence of several types of root pigmentation. Previous investigators classified sorghum seedlings according to the nature of the shoot pigmentation. The present classification is made based on both the shoot and root pigmentations.

Classification of sorghum seedlings based on pigmentation

Shoot pigmentations

The plumules (the seedling shoots) of sorghum seedlings soon after their emergence from the soil are either purple or green. When they are coloured purple they may be either deep purple or purple. The shoot pigmentations are therefore classified into three groups, (1) deep purple, (2) purple, and (3) green. Detailed descriptions of these three groups are given below.

Deep purple shoots

The coleoptile which is the first to emerge from the soil rapidly develops a deep purple tint (Amaranth purple to Aster purple of plate XII in Ridgway's [1912] *Colour Standards*). The young shoot which pushes out of the coleoptile is pigmented likewise. The first two leaves are coloured deeply like the coleoptile. But in later leaves the pigment gradually lightens up and altogether disappears from the sixth to the eighth seedling leaf upwards. As the shoot grows and when the leaf blades begin to spread out, the pigment disappears

from the blade area and is confined to the region of the leaf-sheath only. In seedlings about a week to ten days old and with about four to five leaves, the pigment is seen only on leaf-sheaths. This pigment on leaf-sheaths is very conspicuous and extends even to the bases of the older leaf-sheaths which are at or near the ground level, so much so that even in seedlings about 40 days old the shoot pigment is easily distinguished.

Besides the manifestation of the pigment on the sheath and the blade areas, the auricular junctions (the specialized tissue that connects the blade with the sheath) also get coloured purple from the third leaf onwards. In sorghum, the junctions of the first two leaves are not well developed and the pigment is not seen in these regions. From the third leaf onwards they get well elaborated [Rangaswami Ayyangar, Rao and Rajabhooshanam, 1938] and the pigment is very clearly noticed. Seedlings over a week to ten days old manifest this pigment well. In seedlings of about 20 days old the exposed portions of the outer margins of the leaf-sheaths also develop purple pigment. The development of the purple pigment in the auricular junctions and the leaf-sheath margins is a characteristic of this class of seedlings and these pigmented organs are unmistakable guides in distinguishing this type of shoot pigmentation from the rest.

Purple shoots

In this type the manifestation of the pigment is almost parallel to that of the deep purple type, except that the colour is of a much lighter shade of purple (pale Rosolane purple to light Rosolane purple of plate XXVI in Ridgway's [1912] *Colour Standards*). The coleoptile when emerging from the soil is of a pale greenish tint but very soon becomes purple when outside the soil. The plumular leaves as they come out from the coleoptile are also coloured purple. This colour of the plumular leaves is always of a lighter tint than that of the coleoptile. Except the first two seedling leaves the older leaves do not manifest the purple pigment in the blade area. Even in these two seedling leaves the pigment disappears from the leaf-blade, when they have fully emerged from the coleoptile, and is confined to the leaf-sheaths. Similar to the deep purple shoots, in this type also the bases of the leaf-sheaths at or near the ground level are pigmented purple in seedlings of about 40 days old, though in a faint measure. The auricular junctions and the leaf-sheath margins do not develop purple pigment in this type but remain yellowish green. Besides the difference in the depth of the pigment in the young shoots, the non-manifestation of the pigment in leaf-junctions and leaf-sheath margins clearly helps to distinguish this type of shoot pigmentation from the deep purple type.

Green shoots

In this type the coleoptile and the plumular leaves do not develop purple pigment at any stage of the seedling. The coleoptile when emerging from the soil is either pale yellow or yellowish green. The plumular leaves that push out of the coleoptile are green and remain so thereafter without any trace of purple pigment. The basal region of the older seedling leaves which are at or near the ground level are either yellowish green or green. The auricular junctions and the leaf-sheath margins remain unpigmented. This type

is easily distinguished from the other two pigmented types by the absence of the purple pigment in the coleoptile, plumular leaves, auricular leaf-junctions and leaf-sheath margins.

ROOT PIGMENTATIONS

In sorghum as in other mono-cotyledonous plants the primary root soon dies away and a very large number of secondary roots develop, chiefly from the base of the coleoptile. These roots form the mainstay for the growth of the plant. In young seedlings (up to two to three weeks old) the roots are either colourless or occasionally have a light straw colour. But in seedlings over 20 days old they begin to develop their respective colours. They may be either coloured purple or brown. When coloured purple they may be either reddish purple or blackish purple. There are therefore three pigmented groups in roots, viz. (1) Reddish purple, (2) Blackish purple, and (3) Brown. These three groups are described below :—

Reddish purple roots

These roots at first sight appear brick-red, but on closer examination a faint tint of purple is revealed (Coral-red to Eugenia-red of plate XIII in Ridgway's [1912] *Colour Standards*). The pigment develops first in patches on the older roots in seedlings over 20 days old. These patches gradually begin to coalesce with one another till the entire root looks pigmented. The pigment is not uniformly distributed. On the same root deeper and lighter coloured patches appear. In the early stages of manifestation the pigment is of a lighter tint and gradually deepens later. Generally the older roots get pigmented first, but there is no regularity in colour development on the individual roots. This pigment persists throughout the life of the plant and even after its death in dead tissues.

Blackish purple roots

In this group the roots are coloured black with a slight tinge of purple (Prune purple to Blackish purple of plate IX in Ridgway's [1912] *Colour Standards*). The development, the manifestation and the persistency of the pigment are similar to those of the reddish purple root pigment. The distinction between the reddish purple and the blackish purple colour is clear enough in freshly washed roots. The difference is more markedly seen when the roots are washed and dried in the sun. The reddish purple roots become brick-red in colour, while the blackish purple roots turn black. On drying, the purple part of the pigment which is common to both these types seems to become unobtrusive, the reddish and the blackish nature of the pigment getting emphasized.

Brown roots

These roots do not develop purple pigment, but are coloured yellowish brown to brown (Cream buff to Chamois of plate XXX in Ridgway's [1912] *Colour Standards*). The development, the manifestation and the persistency of the pigment are exactly like those of the purple group. This type is easily distinguished from the other two in that the roots do not possess purple colour at any stage of the plant. When the roots are washed free from the soil, the moist roots are coloured yellowish brown. On drying, this yellow colour disappears and the roots look mere brownish.

RENT TYPES OF SEEDLING COLOURS

sorghum seedlings three kinds of shoot pigmentations and three kinds pigmentations were described in the previous pages. These shoot and igments are two quite different sets of colour manifestations. Any the three shoot pigmentations can combine with any one of the three pigmentations. This combination results in nine different types of ng colours. These are given below.

pe	Seedlings		Reference to Plate IX
	Shoot colour	Root colour	
1	Deep purple	Reddish purple	Fig. 1. A-D
2	,,	Blackish purple	,, 4. A-D
3	,,	Brown	,, 7. A-D
4	Purple	Reddish purple	,, 2. A-D
5	,,	Blackish purple	,, 5. A-D
6	,,	Brown	,, 8. A-D
7	Green	Reddish purple	,, 3. A-D
8	,,	Blackish purple	,, 6. A-D
9	,,	Brown	,, 9. A-D

TION OF SEEDLING COLOURS TO ADULT PLANT PIGMENTATIONS

The sorghum plant manifests purple pigmentation in various places and rious stages in its life period, and the inheritance of these pigments have studied by several investigators. The relationship of the seedling colours some of these pigmentations are discussed below.

The shoot pigmentation of the seedling were found to have an absolute onship with the pigment of the leaf-axils—the basal portion of the inside e leaf-sheath above the region of the nodal band, for brevity called the [Rangaswami Ayyangar, Rao and Reddy, 1938]. When the shoots are e the axils are purple. When the shoots are green the axils are green. ep purple shoots the axils of the plant are likewise coloured deep purple, n addition, the nodal bands, the auricular leaf-junctions and the outer ins of the leaf-sheaths extending from the auricular junctions above to ode below, are also coloured purple. The manifestation of the purple ent in these regions is at its best at the time when the plants are in flower mediately after flowering. This close association in colour manifestation th the seedling and the adult has been so constant that not even an tion was met with in the several thousands of pure lines and numerous gating families studied. Hence it is presumed that the pigmentation in these places is being brought about by the play of the same set of genes. se relationship between the deep purple pigmentation of the plumules on emergence from the soil (the seedling shoots), the axils, the nodal s, the auricular junctions, the leaf-sheath margins and purple colour of the rs was reported by Rangaswami Ayyangar, Rao and Reddy [1938]. n this type of deep purple pigmented shoots the anthers may or may not loured purple. When the shoots are deep purple in colour, irrespective

of the fact whether the anthers are purple or not, the axils, the nodal l the auricular junctions, and the leaf-sheath margins are always coloured p

The root colours have an absolute relationship with those of the sh glume pigmentations reported by Rangaswami Ayyangar [1933]. Whe roots are coloured purple, the leaf-sheaths and glumes are also coloured p When the roots are brown, the leaf-sheaths and glumes are brown. I purple group, the reddish purple roots are associated with reddish purple sheaths and glumes and the blackish purple roots with blackish purple sheaths and glumes. Beside this concurrent manifestation of the pig on the root, leaf-sheath and glume, even portions of midrib, leaf-blade and that get injured when in active growth develop the corresponding root c The pedicelled spikelets, the pulvinor regions of the panicle branches and the stylar end of the grain, in some cases, develop this root pigment

The nine types of seedling pigmentations and their relationship wit adult plant pigmentations presented are in the tabular statement below

No.	Seedling pigmentation			Adult pigmentation	
	Shoot	Root	Axil	Leaf-junctions, leaf-sheath margins and nodal bands	Leaf-she and glu
1	Deep purple	Reddish purple	Deep purple	Purple .	Reddish pu
2	,,	Blackish purple	,,	,,	Blackish pu
3	,,	Brown . .	,,	,, . .	Brown
4	Purple .	Reddish purple	Purple .	Green . .	Reddish pu
5	,, .	Blackish purple	,, . .	,, . .	Blackish pu
6	,, .	Brown . .	,, . .	,, . .	Brown
7	Green .	Reddish purple	Green . .	,, . .	Reddish pu
8	,, .	Blackish purple	,, . .	,, . .	Blackish pu
9	,, .	Brown . .	,, . .	,, . .	Brown

Genetic analysis of the seedling colours

Shoot pigmentations

The inheritance of the shoot pigmentation was pursued in 20 crosses these the inheritance up to the third generation was studied in eight. results are discussed below :—

A factor **PC** [Rangaswami Ayyangar, 1938] is responsible for the pre of the purple colour in the coleoptile and the young shoot. In its ab (**pc**) the coleoptile and the shoot are green. Purple (**PC**) is a simple dom to green (**pc**). A factor **PJ** operating in the presence of the purple f **PC** makes the coleoptile and the shoot deep purple and produces purple mentation in the leaf-junctions and leaf-sheath margins in addition. has no visible effect in the absence of **PC**. These factor pairs **PCPC PJPJ** result in the following genic constitution of the three groups :—

1. Deep purple **PCPCPJPJ**
2. Purple **PCPCpj pj**
3. Green **pcpcPJPJ** or **pcpcpjpj**

The interplay of these two factors results in the usual monohybrid and dihybrid ratios. Segregations for these three shoot pigmentations are presented in the following tables. Tables I—III give simple monogenic segregations and Table IV gives the dihybrid segregation.

TABLE I

Pure for **pj** *and segregating for* **PC**

(Shoots purple to green)

ration	Family number	Character of selection: Shoot colour	Behaviour of progeny: Shoot colour — Purple	Green
ts	A S 2177	Purple		
	„ 1633	Green		
	„ CLIV	Purple		
	„ 3717	....	202	68
	„ 3718	....	375	136
	„ 3719	....	152	61
	„ 3720	....	340	99
		Total	1069	364
		Expected 3 : 1 ratio	1074·75	358·25
		$\chi^2 = 0 \cdot 120$	$P > 0 \cdot 70$	
	A S 4456	Purple	186	78
	„ 4457	„	650	237
	„ 4460	„	593	207
	„ 4461	„	361	109
	„ 4462	„	485	115
	„ 4463	„	324	120
	„ 4465	„	63	20
	„ 4466	„	679	216
	„ 4470	„	187	69
	„ 4459	„	Pure	..
	„ 4468	„	„	..
	„ 4469	„	„	..
	„ 4465	Green	..	Pure
	„ 4458	„	..	„
	„ 4464	„	..	„
	„ 4467	„	..	„
		Total	3528	1171
		Expected 3 : 1 ratio	3524·25	1174·75
		$\chi^2 = 0 \cdot 0159$	$P > 0 \cdot 80$	

The inheritance of this factor pair **PCPC** was pursued in 40 other fa
These gave a total of 6815 seedlings with purple and 2238 seedlings with
shoots in the F_2 generation and 6071 purple and 1958 green in the F_3 g
tion.

TABLE II

Pure for **PJ** *and segregating for* **PC**

(Shoots deep purple to green)

Generation	Family No.	Character of selection	Behaviour of progeny	
		Shoot colour	Shoot colour	
			Deep purple	Gree
F_1	A S 3999	Deep purple		
F_2	,, 4847 .	,, .	369	12
	,, 4848 .	,, . .	252	8
	,, 4849 .	,, . .	291	10
		Total .	912	31
		Expected 3 : 1 ratio .	922·5	30
		$\chi^2 = 0{\cdot}4780$	$P > 0{\cdot}30$	
F_3	A S 5725 .	Deep purple . .	284	10
	,, 5726 .	,, . .	275	10
	,, 5727 .	,, . .	160	6
	,, 5729 .	,, . .	431	14
	,, 5731 .	,, . .	204	7
	,, 5732 .	,, . .	240	8
	,, 5728 .	,, . .	Pure	8
	,, 5730 .	,, . .	,,	8
	,, 5733 .	Green . . .	,,	Pur
	,, 5734 .	,, . . .	,,	,,
		Total .	1594 .	56
		Expected 3 : 1 ratio	1617	53
		$\chi^2 = 1{\cdot}3085$	$P > 0{\cdot}20$	

The same experience was met with in eight other families and the seg
tion figures of the F_2 generation are 375 deep purple and 110 green a
the F_3 generation 2547 deep purple and 840 green shoots.

TABLE III

Pure for **PC** *and segregating for* **PJ**

(Shoots deep purple to purple)

Generation	Family No.	Character of selection	Behaviour of progeny	
		Shoot colour	Shoot colour	
			Deep purple	Purple
Parents	A S 3447 .	Deep purple		
	„ 60	Purple		
F_1	„ CCXV	Deep purple . .		
F_2	„ 4756 .	„ . .	474	167
	„ 4757 .	„ . .	366	127
		Total .	840	294
		Expected 3 : 1 ratio	850·5	283·5
			$\chi^2 = 0{\cdot}5185$	$P > 0{\cdot}30$
F_3	A S 5511 .	Deep purple . .	235	85
	„ 5512 .	„ . .	210	65
	„ 5513 .	„ . .	204	67
	„ 5514 .	„ . .	Pure	67
		Total .	649	217
		Expected 3 : 1 ratio .	649·5	216·5
			$\chi^2 = 0{\cdot}00154$	$P > 0{\cdot}95$

The above experience was met with in 27 other families. These gave a total of 1386 deep purple and 462 purple in the F_2 and 6376 deep purple and 2029 purple shoots in the F_3 generations.

The dihybrid segregation involving both the factors **PC** and **PJ** was pursued in a family M S 1428 for three generations. M S 1428 is a selection from Tanganyika with purple shoot colour. In it a natural cross A S 3949 with deep purple shoot colour was obtained. When sown, this segregated and a dihybrid segregation involving the three groups, deep purple, purple and green shoots, was obtained. Twenty-three selections were carried forward from this F_2 generation and an F_3 population raised. In the F_3 generation, the dihybrid segregation of the F_2 together with other simple monogenic segregations were obtained. These are given in Table IV :—

TABLE IV

Segregating for **PC_t** *and* **PJ**

(Shoots deep purple, purple and green)

Generation	Family No.	Character of selection	Behaviour of progeny		
			Shoot colour		
		Shoot colour	Deep purple	Purple	Green
	M S 1428 family				
F_2	A S 3949 .	Deep purple . . .	53	13	18
		Expected 9 : 3 : 4 ratio	47·25	15·75	21
		$\chi^2 = 1·6084$		$P > 0·30$	
F_3	A S 4812 .	Deep purple . .	229	59	91
	,, 4813 .	,, . .	236	81	108
	,, 4814 .	,, . .	215	65	76
	,, 4815 .	,, . .	291	107	119
	,, 4820 .	,, . .	225	67	98
	,, 4832 .	,, . .	63	17	27
		Total .	1259	396	519
		Expected 9 : 3 : 4 ratio	1229·9	407·6	543·5
		$\chi_2 = 2·5001$		$P > 0·20$	
	A S 4816 .	Deep purple . .	364	121	..
	,, 4817 .	,, . .	138	31	..
	,, 4818 .	,, . .	389	153	..
	,, 4819 .	,, . .	329	81	..
		Total .	1220	386	..
		Expected 3 : 1 ratio	1204·5	401·5	
		$\chi^2 = 0·7978$		$P > 0·30$	
	A S 4834 .	Deep purple . .	383	..	125
	,, 4835	,, . .	136	..	47
		Total .	519	..	172
		Expected 3 : 1 ratio	518·25	..	172·75
		$\chi^2 = 0·00108$		$P > 0·95$	
	A S 4822 .	Deep purple . . .	Pure	..	..
	,, 4823 .	Purple . . .	..	243	67
	,, 4824 .	,, . . .	..	346	96
	,, 4825 .	,, . . .	..	212	68
	,, 4826 .	,, . . .	..	261	91
	,, 4827 .	,, . . .	..	Pure	..
		Total .	..	1062	322
		Expected 3 : 1 ratio	..	1038	346
			$\chi^2 = 2·2196$	$P > 0·10$	
	A S 4828 .	Green . . .	,,	,,	Pure
	,, 4829 .	,, . . .	,,	,,	,,
	,, 4830 .	,, . . .	,,	,,	,,
	,, 4831 .	,, . . .	,,	,,	,,
	,, 4836 .	,, . . .	,,	,,	,,

Genetic analysis of the root pigmentations

The inheritance of the root pigmentations has been studied in 21 crosses. Segregations up to the third generation were pursued in 11 of these.

The factor **P** [Rangaswami Ayyangar, 1938] is present in the purple group and absent in the brown. Purple is a simple dominant to brown. The purple group is divisible into two sub-groups, one with the factor **Q** [Rangaswami Ayyangar, 1938] which makes the roots reddish purple and the other without it which results in the roots appearing blackish purple. The former is dominant to the latter. These two factors **P** and **Q** result in the following genic constitutions of the three groups.

1. Reddish purple **PPQQ**
2. Blackish purple **PPqq**
3. Brown **ppQQ**
   or **ppqq**

The interplay of these two factors results in the usual monohybrid and dihybrid ratios. Segregations for these three root pigmentations are presented in the following tables. Tables V-VII give simple monogenic segregations for one or the other of the two factors. Table VIII gives the dihybrid segregation.

Table V

Pure for **q** *and segregating for* **P**

(Roots blackish purple to-Brown)

Generation	Family No.	Character of selection	Behaviour of progeny	
			Root colour	
		Root colour	Blackish purple	Brown
Parents	A S 4068	Blackish purple		
	„ 2380	Brown		
F_1	„ CCLXXVIII	Blackish purple		
F_2	„ 6411	„	355	120
	„ 6412	„	210	75
		Total	565	195
		Expected 3 : 1 ratio	570	190
			$\chi^2 = 0 \cdot 1754$	$P > 0 \cdot 50$
F_3	A S 6451	Blackish purple	320	112
	„ 6452	„	272	87
	„ 6454	„	286	93
	„ 6455	„	315	107
	„ 6456	„	292	102
	„ 6457	„	198	63
	„ 6459	„	295	98
	„ 6460	„	356	121
	„ 6453	„	Pure	..
	„ 6458	„	„	..
		Total	2334	783
		Expected 3 : 1 ratio	2337·75	779·25
			$\chi^2 = 0 \cdot 0240$	$P > 0 \cdot 80$

The same experience was met with in 18 other families. Three of these gave a total of 410 plants with blackish purple and 145 plants with brown root in the F_2 generation and the other 15 gave a total of 1305 blackish purple and 384 brown rooted plants in the F_3 generation.

TABLE VI

Pure for **Q** *and segregating for* **P**

(Roots reddish purple to brown)

Generation	Family No.	Character of selection: Root colour	Behaviour of progeny: Root colour	
			Reddish purple	Brown
Parents	A S 3834 .	Reddish purple		
	„ 2487 .	Brown		
F_1	„ CCLXXIII	Reddish purple . .		
F_2	„ 5272 .	„ . .	287	99
	„ 5273 .	„ . .	156	56
	„ 5274 .	„ . .	325	115
	„ 5275 .	„ . .	205	69
		Total .	973	339
		Expected 3 : 1 ratio	984	328
			$\chi^2 = 0{\cdot}4918$	$P > 0{\cdot}30$
F_3	A S 6067 .	Reddish purple . .	200	68
	„ 6071 .	„ . .	270	88
	„ 6072 .	„ . .	175	62
	„ 6068 .	„ . .	Pure	..
	„ 6069 .	„ . .	„	..
		Total .	645	218
		Expected 3 : 1 ratio	647·25	215·75
			$\chi^2 = 0{\cdot}0312$	$P > 0{\cdot}80$

The same experience was met with in 11 other families. Six families gave 2343 reddish purple and 922 brown in the F_2 and the other five families gave 1316 reddish purple and 483 brown in the F_3 generation.

TABLE VII

Pure for **P** *and segregating for* **Q**

(Roots reddish purple to blackish purple)

eneration	Family No.	Character of selection: Root colour	Behaviour of progeny: Root colour — Reddish purple	Blackish purple
ents	A S 4249	Reddish purple		
	„ 29	Blackish purple		
1	„ CCLXVI	Reddish purple		
2	„ 5429	....	435	138
	„ 5430	....	392	126
		Total	827	264
		Expected 3 : 1 ratio	818·25	272·75
		$\chi^2 = 0{\cdot}374$	$P > 0{\cdot}50$	
3	A S 6403	Reddish purple	151	45
	„ 6306	„	65	25
	„ 6307	„	64	23
	„ 6305	„	Pure	..
	„ 6308	Blackish purple	..	Pure
		Total	280	93
		Expected 3 : 1 ratio	279·75	93·25
		$\chi^2 = 0{\cdot}0008$	$P > 0{\cdot}95$	

The same experience was met with in 73 other families. Of these 21 milies gave a total of 5537 reddish purple and 1861 blackish purple in the and the rest 47 families gave a total of 12,489 reddish purple and 4,123 ckish purple in the F_3 generation.

The dihybrid segregation involving the factors **P** and **Q** was pursued in ss A S CCLXXXII each parent contributing one dominant gene. The ents involved are A S 4564, a blackish purple root selection and consently of the constitution **PPqq**, and A S 2487, a brown root selection of constitution **ppQQ**. In the F_1 generation both the dominant genes are ught together resulting in the reddish purple roots. In the F_2 generation ihybrid ratio was obtained. From the F_2 generation a number of selecns were carried forward to a third generation and as expected both the ihybrid and monohybrid segregations were obtained. This experience is en in Table VIII.

TABLE VIII

Segregating for **P** *and* **Q**

(Roots reddish purple, blackish purple and brown)

Generation	Family No.	Character of selection	Behaviour of progeny		
		Root colour	Root colour		
			Reddish purple	Blackish purple	Brown
Parents	A S 4564 .	Blackish purple .			
	„ 2487	Brown			
F_1	„ CCLXXXII	Reddish purple .			
F_2	„ 6153 .	„ .	268	84	101
	„ 6154 .	„ .	302	98	126
	„ 6155 .	„ .	283	97	125
		Total .	853	279	352
		Expected 9: 3 : 4 ratio	834·75	270·25	371
			$\chi^2 = 1{\cdot}3739$		$P > 0{\cdot}50$
F_3	A S 6462 .	Reddish purple .	165	45	63
	„ 6463 .	„ .	71	26	34
	„ 6464 .	„ .	63	22	31
		Total .	299	93	128
		Expected 9: 3 : 4 ratio	292·5	97·5	130
			$\chi^2 = 0{\cdot}3828$		$P > 0{\cdot}80$
	A S 6465 .	Reddish purple .	120	36	..
		Expected 3 : 1 ratio	117	39	..
			$\chi^2 = 0{\cdot}3077$		$P > 0{\cdot}50$
	A S 6461 .	Reddish purple .	153	..	49
		Expected 3 : 1 ratio	151·5	..	50·5
			$\chi^2 = 0{\cdot}0594$		$P > 0{\cdot}80$
	A S 6466 .	Brown . . .	..	..	Pure
	„ 6467 .	„ . . .	..	..	„

The same experience was met with in 28 other families. Sixteen of thes gave a total of plants with 3778 reddish purple, 1215 blackish purple and 166 brown roots in the F_2 generation and the rest 12 familes gave a total of 306 reddish purple, 980 blackish purple and 1354 brown roots in the F_3 generation

INTER-RELATIONSHIP OF SHOOT AND ROOT PIGMENTATION GENES

The inheritance of the factor pairs **PCPC** and **PJPJ** determining the shoot pigmentations, and of the factor pairs **PP** and **QQ** determining the root pigmentations have been discussed in the previous pages. The inter-relationship of these four factor pairs will be dealt with in this part. The cross collations and linkages discussed in this part are from artificial crosses designed for the purpose. The linkage relationships are studied both in the coupling and in the repulsion phases and the segregations are pursued up to the third generation. The results are discussed below.

The factor pair **PCPC** is independent of **QQ** and is linked with **P** with a cross-over value of 18·0 per cent. The factor pair **PJPJ** is independent of **QQ** and **PP**. Hence it follows that these four pairs of genes are distributed in three pairs of chromosomes, **PP** and **PCPC** being located in one and the same chromosome. Data relating to the above relationship is presented in Tables IX—XIII.

TABLE IX

Crosses with the factor pairs **QQ** *and* **PC PC**

Generation	Family No.	Behaviour of the progeny			
		Shoot	Purple	Green	
		Root	Reddish purple	Blackish purple	Reddish purple	Blackish purple
Parents	A S 367 .		♀	—	—	—
	„ 3464 .		..	—	—	♂
F_1	„ CCVIII		F_1			
F_2	„ 4391 .		385	128	131	39
	„ 4393 .		365	124	122	38
	„ 4394 .		392	127	142	42
	„ 4396 .		420	134	124	30
	Total .		1562	513	529	149
Expected 9 : 3 : 3 : 1 ratio			1548·56	516·19	516·19	172·06
			$\chi^2 = 3 \cdot 5447$		$P > 0 \cdot 30$	
F_3	A S 5341 .		165	52	58	21
	„ 5346 .		301	95	101	35
	„ 5349 .		256	82	87	30
	„ 5350 .		360	111	122	41
	„ 5352 .		156	51	56	20
	„ 5353 .		115	41	39	12
	„ 5363 .		260	82	93	25
	„ 5364 .		160	56	52	18
	„ 5365 .		143	42	47	18
	„ 5368 .		138	43	41	17
	„ 5370 .		24	7	7	3
	Total .		2078	662	703	240
Expected 9 : 3 : 3 : 1 ratio			2071·69	690·56	690·56	230·19
			$\chi^2 = 1 \cdot 8425$		$P > 0 \cdot 50$	

The above experience shows that **PC** is independent of **Q**. Similar dihybrid segregations are obtained in six other families and the total figures are :

Shoot	Purple		Green	
Root	Reddish purple	Blackish purple	Reddish purple	Blackish purple
Expected 9 : 3 : 3 : 1	1244 1234·31	392 411·44	385 411·44	120 133·81

$\chi^2 = 4 \cdot 1187$ $P > 0 \cdot 20$

TABLE X

Crosses with the factor pairs **PJ PJ** *and* **QQ**

Generation	Family No.	Behaviour of the progeny			
		Shoot	Deep purple		Purple	
		Root	Reddish purple	Blackish purple	Reddish purple	Blackish purple
Parents	A S 3447		—	♀	..	—
	„ 60		—	—	♂	—
F_1	„ CCXV		F_1			
F_2	„ 4756		356	118	121	46
	„ 4757		257	91	95	32
	Total		613	209	216	78
Expected 9 : 3 : 1 ratio			627·8	209·2	209·2	6·98
			$\chi^2 = 1 \cdot 5402$		$P = 0 \cdot 50$	
F_3	A S 4850		170	50	59	18
	„ 4961		71	23	20	7
	„ 4962		236	98	94	34
	Total		477	171	173	59
Expected 9 : 3 : 3 : 1 ratio			495	165	165	55
			$\chi^2 = 1 \cdot 5514$		$P > 0 \cdot 50$	

From Table X it is evident that **PJ** is independent of **Q**. Similar dihybrid segregations were obtained in five other families and the total of these comes to :

Shoot	Deep purple		Purple	
Root	Reddish purple	Blackish purple	Reddish purple	Blackish purple
Expected 9 : 3 : 3 : 1	460 435·94	136 145·31	134 145·31	45 48·44

$\chi^2 = 3 \cdot 0482$ $P > 0 \cdot 30$

TABLE XI

Segregations with the factor pairs **PJPJ** *and* **PP**

Family number	Behaviour of the progeny				
	Shoot	Deep purple		Purple	
	Root	Reddish purple	Brown	Reddish purple	Brown
atural crosses from Family					
A S 1933—					
,, 4774 . . .		375	120	128	41
,, 4775 . . .		410	135	138	48
,, 4776 . . .		270	85	88	25
Total .		1055	340	354	114
Expected 9 : 3 : 3 : 1 ratio		1047·94	349·31	349·31	116·44
		$\chi^2 = 0{\cdot}4096$		$P > 0{\cdot}90$	

From Table XI it is seen that **PJPJ** and **PP** are independent.

TABLE XII

Crosses with the factor pairs **PCPC** *and* **PP**

eneration	Family No.	Behaviour of progeny				
		Shoot	Purple		Green	
		Root	Purple	Brown	Purple	Brown
arents	A S 2487		—	♀	—	–
	,, 1745		—	—	♂	–
F_1	,, CCLXXV		F_1	—	—	—
F_2	,, 5276 .		213	98	90	3
	,, 5277 .		286	125	122	4
	,, 5278 .		550	240	256	8
	Total .		1049	463	468	15
	Calculated 9 : 3 : 3 : 1 ratio		1122·2	374·1	374·1	124·6
			$\chi^2 = 141{\cdot}8088$		$P < 0{\cdot}01$	

The high value of χ^2 shows that the distribution of the four groups do not conform to the normal dihybrid ratio. The **P** value is much below 0. Such a distribution of the four groups as that obtained above can be exp ne only on the assumption of a linkage between the factor **PC** for purple colour and the factor **P** for the purple root colour. On this a sum ri the recombination percentage was worked out and a value of $18 \cdot 2 \pm 1 \cdot \cdot$ we obtained. On the assumption of linkage with a recombination percent e 18, the expected distribution of the four groups is as follows :

Shoot	Purple		Green	
Root	Purple	Brown	Purple	Brow
Numbers obtained . . .	1049	463	468	15
Calculated (18 per cent crossing over)	1013·66	482·59	482·59	16·16

$\chi^2 = 2 \cdot 5515$ $P > 0 \cdot 30$

The value of $\chi^2 = 2 \cdot 5515$ with P greater than 0·30 shows that the assu tion of linkage with 18 per cent crossing over satisfactorily explains this de tion from the usual simple dihybrid ratio.

From the family A S 5276, two more selections were carried forw and a third generation raised. Both these selections segregated repeating th experience of the F_2 generation. On the assumption of the same linkage as i the F_2 with a recombination value of 18 per cent the distribution of the fou groups is as follows :—

Shoot	Purple		Green	
Root	Purple	Brown	Purple	Brown
A S 6080	192	88	82	3
„ 6081	302	150	148	4
Total .	494	238	230	7
Calculated (18 per cent crossing over)	492·35	234·40	234·40	7·15

$\chi^2 = 0 \cdot 2353$ $P > 0 \cdot 95$

The above linkage between the factor pairs **PCPC** and **PP** is in th repulsion phase. The same experience was obtained in the coupling phas also, and the results are given in Table XIII.

TABLE XIII

Crosses with the factor pairs **PctPct** *and* **PP**

eration	Family No.	Behaviour of progeny: Shoot	Purple		Green	
		Root	Purple	Brown	Purple	Brown
ts	A S 60 .		♀	—	—	—
	,, 4174 .	—	—	—	—	♂
	,, CCLVIII		F_1	—	—	—
	,, 5420 .		442	69	65	120
	,, 5421 .		495	70	65	130
	Total .		937	139	130	250
lated (18 per cent crossing over) .			972·75	119·25	119·25	244·75

$\chi^2 = 5 \cdot 6662$ $P > 0 \cdot 10$

From family A S 5420 two more selections were carried forward and a generation raised. The results are given below :—

Shoot	Purple		Green	
Root	Purple	Brown	Purple	Brown
6296	168	34	35	55
6297	275	35	30	61
Total .	443	69	65	116
lated (18 per cent crossing over)	462·99	56·76	56·76	116·49

$\chi^2 = 4 \cdot 7006$ $P > 0 \cdot 10$

From the above experience it is evident that the factor **PC** for the purple ur of the shoot and the factor **P** for the purple colour of the root are linked a crossing-over percentage of 18.

PIGMENTATION OF THE MESOCOTYL

A feature in which grass seedlings differ from those of other mono-cotyle- s in general is the frequent presence of a segment inserted between the ledon sucker and the sheath which encloses the plumular bud. This ment is called the mesocotyl [Arber, 1934].

In sorghum, the mesocotyl grows to remarkable lengths and is the organ responsible for the emergence of the young shoot from the When the seeds are sown near the ground level, the mesocotyl is short b they are sown deep, the mesocotyl elongates and thus enables the shoo emerge out of the soil [Rangaswami Ayyangar and Nambiar, 1934].

Under normal conditions the mesocotyl is always below the soil a is found that in such cases it always develops the colour of the roots. I roots are purple, the mesocotyl is purple. If the roots are brown, the m cotyl is likewise brown. It is noti ed that long before the manifestatio the pigment in the roots, the mesocotyl develops the colour and is alway easy guide for determining the root pigmentation. The next step was t to grow the mesocotyl above the soil in presence of light like the shoot. this purpose, seeds were sown in trays filled with soil and grown in dark for two to three days. The seedlings in darkness became etiolated and mesocotyl region grew out of the soil to a very long length. When exami no trace of the pigment was seen either in the young shoot or in the mesoco The trays were then taken out from darkness and exposed to light. shoots slowly developed their corresponding pigmentation. It was v interesting to observe that the mesocotyl region also along with the sh began to develop the shoot pigmentation. If the shoots were deep pur the mesocotyls developed deep purple colour. If the shoots were purple, mesocotyls were purple. In green shoots the mesocotyls remained colourl

Thus it is seen that the mesocotyl which under normal conditions is alw below the soil and possesses the root colour when made to grow above soil in presence of light develops the shoot colour. This differential respo of this organ to the development of the pigment under different environmen conditions, behaving sometimes as shoot and sometimes as root, is very int esting and is probably brought about as a result of the change in functio this organ under the different environmental conditions.

Summary

The sorghum plant manifests several types of pigmentation in the seedl stage. Both the shoot and the roots develop different types of pigmentati A classification of the seedlings is made based on both these shoot and r pigmentations.

There are three types of shoot pigmentations, deep purple, purple green. In the deep purple type, the coleoptile and the young shoot close emergence from the soil are coloured deep purple, and in the seedling, auricular leaf-junctions and the outer margins of the leaf-sheaths are colou purple. In the purple type, the coleoptile and the young shoot are colou purple, while the auricular junctions and the leaf-sheath margins are purple pigmented. In the green type, the coleoptile, the young shoot, auricular junctions and the leaf-sheath margins are green without any pur in them.

There are three types of root pigmentations, reddish purple, black purple and brown. These colours manifest when the seedlings are about or more days old. The reddish purple roots are brick-red with a tinge purple colour in them. When dried they loose the purple tint and beco

k-red. The blackish purple roots are likewise black with a slight tint of ple. On drying the purple tinge disappears and the roots ultimately become k. In the brown type the roots are yellowish brown when fresh and drying become brown to straw in colour.

Based on these shoot and root pigmentations, sorghum seedlings are sified into nine pigmentation groups :—

These seedling pigmentations have a definite relationship with some of adult plant pigmentations. When the shoots are deep purple, the leaf- s are likewise coloured deep purple and the leaf-junctions, the leaf-sheath gins and the nodal bands are coloured purple. When the shoots are purple, leaf-axils alone are coloured purple and the other regions are green. When shoots are green, all these regions including the leaf-axils are green with- any trace of purple in them. When the roots are coloured purple, the leaf- aths and the glumes of the plant are also purple. When the roots are brown, leaf-sheaths and glumes are likewise brown. The reddish purple roots are ociated with reddish purple leaf-sheaths and glumes, and the blackish pur- roots with blackish purple leaf-sheaths and glumes. This relation between seedling and the adult pigmentation is absolute and probably due to the ion of the same genes. The mesocotyl develops either the root or the shoot mentation according as it is under the soil like the roots or grows above the und (normally rare) like the shoot.

In inheritance, a factor **PC** is responsible for the purple pigmentation of young shoot. In its absence (**pc**) the shoot is green. A factor **PJ** acting presence of **PC** makes the shoot deep purple and colours the leaf-junctions l leaf-sheath margins purple. **PJ** has no visible effect in the absence of **PC**. factor **P** is present in the purple-coloured roots and absent in the brown. factor **Q** makes the roots reddish purple ; **q** results in blackish purple roots. e factor **PC** is independent of **Q** and is linked with **P** with a cross-over value 18 per cent. The factor **P** is independent of **PJ** which again is independent **Q**.

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EXPLANATION OF PLATE IX

The plate is divided into nine sections, numbered 1 to 9. In these nine sections are shown the nine pigmented types of sorghum seedlings and the related pigmented parts of the adult.

Section No.	Seedlings	
	Shoot	Roots
1	Deep purple	Reddish purple
2	Purple	,, ,,
3	Green	,, ,,
4	Deep purple	Blackish purple
5	Purple	,, ,,
6	Green	,, ,,
7	Deep purple	Brown
8	Purple	,,
9	Green	,,

In each section, A represents a seedling five days old ; B leaf-axil : C leaf-junctions ; D roots of a seedling 20 days old ; E internode with the leaf-sheath at maturity showing the nodal bands ; and F mature glumes enclosing a well-developed grain.

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[*For explanation see opposite page*

In the deep purple shoot type (Nos. 1, 4 and 7), the coleoptile and the plumule of the seedling A, the leaf-axil B, the leaf-junctions C and the nodal bands in E, are pigmented deep purple. In the purple shoot type (Nos. 2, 5 and 8), the coleoptile is light purple and the plumular leaves are merely tinged purple ; the leaf-axil is light purple, while the leaf-junctions and the nodal bands are green. In the green shoot type (Nos. 3, 6 and 9) the coleoptile, the plumular leaves, the leaf-axil, the leaf-junctions and nodal bands are green without any trace of purple in any one of these parts.

In the reddish purple root type (Nos. 1, 2 and 3), the seedling roots D, the mature leaf-sheath E and the glumes F, are pigmented reddish purple. In the blackish purple type (Nos. 4, 5 and 6), all these parts are pigmented blackish purple, and in the brown type (Nos. 7, 8 and 9), these are brown.

EFFECT OF COTTON SEED DISINFECTION ON YIELD

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DAMPING-OFF and seedling-blight diseases of cotton are caused in t provinces by *Pythium* sp., *Macrophomina phaseoli* Ashby, *Rhizoct solani* Kuhn., *Rhizoctonia* sp., *Sclerotium Rolfsii* Sacc. and *Colletotric indicum* Dast. These fungi often cause poor germination and consider loss of seedlings. Trials were carried out for the control of these dise by treating the seed. During the trials it was found that the incidenc these diseases is not annual and not always of the same intensity. The disposing factors are excessive moisture caused by heavy rainfall and wa logging during the critical period, the first three or four weeks after germ tion, when the seedlings are most susceptible to infection by these fungi, in the case of the anthracnose disease (*Colletotrichum indicum*) of seedl the use of infected seed. For these reasons the value of seed treatment the control of these diseases is not well established except in the case of seed-borne anthracnose disease [Dastur, 1934]. However, there is evid that the mortality of seedlings raised from disinfected seeds is less than of seedlings from untreated seeds in years when there is an epidemic of t diseases. But these trials have shown the value of seed disinfection in creasing the yield.

In Nagpur, these trials have been carried out since 1936 and for the two years these treatments have been tried on some of the district fa as well. The seed treatments tried at Nagpur were dusting with Agr G, Hortosan B, Abavit B, Ceresan, finely powdered copper carbonate sulphur, and delinting with sulphuric acid. The four proprietary fu cides were used at the rate of one ounce per 28 lb. of seed ; the two chem were used at the rate of two ounces per 28 lb. of seed ; for delinting the with sulphuric acid one part by volume of the acid was used for 20 part volume of the seed.

It is a general practice amongst cultivators of the province to wet cotton seed with a cowdung solution so that, on drying, the fuzz is set and seed passes readily through the drill. The fungicide in the powder was well mixed with the cowdung solution before it was applied to the

Delinting with sulphuric acid was carried out as described in a prev publication [Dastur, 1934].

In 1936 each treatment was tried on 1/40 acre plot and replic three times. Each block consisted of these seven treatments and one trol. The three blocks were placed contiguously. The following year trials were repeated ; each treatment and the control were tried on acre plots and replicated three times. In 1938, these trials were again ca out with the same number of replications but each plot was 1/20 acre.

It was observed that the delinted seeds germinated earlier by a day or two than the other seeds. The plants in the control plots were at first smaller than those in plots sown with treated seed. This difference in growth was noticeable only up to about two months after sowing ; but when the flowering stage was reached, there was no visible difference in the size of the plants.

The yield of *kapas* (seed cotton) from the plots sown with treated seed was higher than that from the control plots during these three years.

As the treated seed in the trials had given a higher yield than the untreated seed, it was considered desirable to increase the number of replications and to test only those fungicides which are readily procured in India and which can be easily used by the cultivator. Ceresan is not marketed in India : delinting seed with sulphuric acid cannot be done by the ordinary cultivator : therefore, these two treatments were not tried again. In 1939 and 1940, each plot was 1/20 acre and the replications were six : the treated and untreated seeds were sown in randomized plots. The percentage of increase in yield from the five years' trials are given below :—

Treatment	1936-37	1937-38	1938-39	1939-40	1940-41
Agrosan G . . .	14·4	27·0	38·3	19·0	1·7
Hortosan B . . .	9·1	20·6	44·6	21·1	21·2
Abavit B	8·0	13·9	40·3	17·5	5·9
Ceresan	16·3	25·9	25·9	..	..
Copper carbonate . .	25·3	24·9	38·9	8·2	12·7
Sulphur	15·2	29·9	33·7	19·5	12·4
Delinted seed . . .	8·7	9·9	10·4	..	..

In 1940, the monsoon was unseasonable and, when it broke, the rains were abnormally heavy and continuous : the result was that all the six blocks could not be sown on the same day : a block and a half were sown on 30 June ; further sowing could not be done till 8 July when only 3½ blocks could be sown ; the remaining sixth block could not be sown on account of rain. No further sowing was possible till 25 July. The fields got flooded and some of the plots sown on 8 July were under water for many days ; either seeds were washed away or seedlings were killed. For these reasons the yield from only a few plots could be considered, those that were sown in the end of June and some of those that were sown on 8 July. Last year's results cannot be therefore compared with those of the previous four years.

In 1939 and 1940, three of these fungicides were tried out on the Akola Farm. Each plot was 1/4 acre and replicated four times. The plots were randomized. The percentage of increase in yield is given below :—

Treatment	1939-40	1940-41
Agrosan G	11·3	12·5
Copper carbonate	11·8	4·7
Sulphur	10·6	1·9

At the Government Farm, Khandwa, in 1939 seed treated with Agrosan G and copper carbonate were sown on 0·3 acre plots with six replications. The control plot was also replicated six times. In 1940, the size of each of these three plots was 1/20 acre ; each plot was replicated six times. These trials were carried out in randomized plots. The percentage of increase in yield is given below :—

Treatment	1939-40	1940-41
Agrosan G	26·5	10·4
Copper carbonate	12·4	6·8

On a demonstration plot at Amraoti, Agrosan G and sulphur treatments were tried in 1939 and 1940. The 1940 trials were vitiated on account of the unseasonal and abnormal rainfall, and therefore the results of the 1940 trials cannot be considered. In 1939, seeds treated with Agrosan G and with sulphur were sown on two-acre plots each and the untreated seed was sown on a one-acre plot. The percentage of increase of yield from the plots sown with seed treated with Agrosan G and sulphur was 16·2 and 11·5 respectively.

On the Government Farm at Ellichpur in 1939, a field of 10 acres was divided into four equal plots of $2\frac{1}{2}$ acres each ; one plot was sown with seed treated with Agrosan G, another plot with copper carbonate-treated seed and the remaining two plots were sown with untreated seed and alternated with the plots sown with the treated seed. The yield from the plot sown with seed treated with Agrosan G was 14·7 per cent higher than that from the control plots, but the yield from the plot sown with seed treated with copper carbonate was less by 19·4 per cent.

The following year these two fungicides were tried again on this Farm two fields separated from each other. In one field each plot was 1/3 re and replicated five times. On the second field these trials were re- ated six times in randomized plots of 1/20 acre each. The percentage of crease in yield from these two plots is given below :—

Treatment	Field I	Field II
grosan G	12·6	7·6
opper carbonate	7·6	5·3

It is not possible to give a precise explanation for the lower yield obtained om the plot sown with copper carbonate-treated seed in 1939. But since ne following year on two fields on the same Farm the yield was higher than om the control plots, it is permissible to assume that the lower yield in 939 could not be due to the treatment.

In 1940, some of these treatments were tried at Borgaon and Yeotmal arms. Each of the plots sown with treated and untreated seed was 1/20 re and replicated six times. The percentages of increase in yield are given elow :—

Treatment	Borgaon Farm	Yeotmal Farm
grosan G	2·0	31·2
opper carbonate	6·8	19·0
ulphur	9·6	32·5

The results of these experiments, which have been carried out for many ears and on various Government Farms, show that chemical treatment of otton seed increases the yield of *kapas* (seed cotton) ; the percentage of crease is variable, but is sufficient to justify the use of treated seed ; seed atment is inexpensive and does not need any extra labour or skill or care. ne treatment with fungicides not only ensures increase in yield but also is apable of destroying fungus spores, e.g. spores of the anthracnose fungus ; his disinfection of the seed would naturally ensure better germination and eduction in loss from disease, especially when conditions are unfavourable or quick germination.

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STEM-BROWN DISEASE OF APPLE IN KUMAUN

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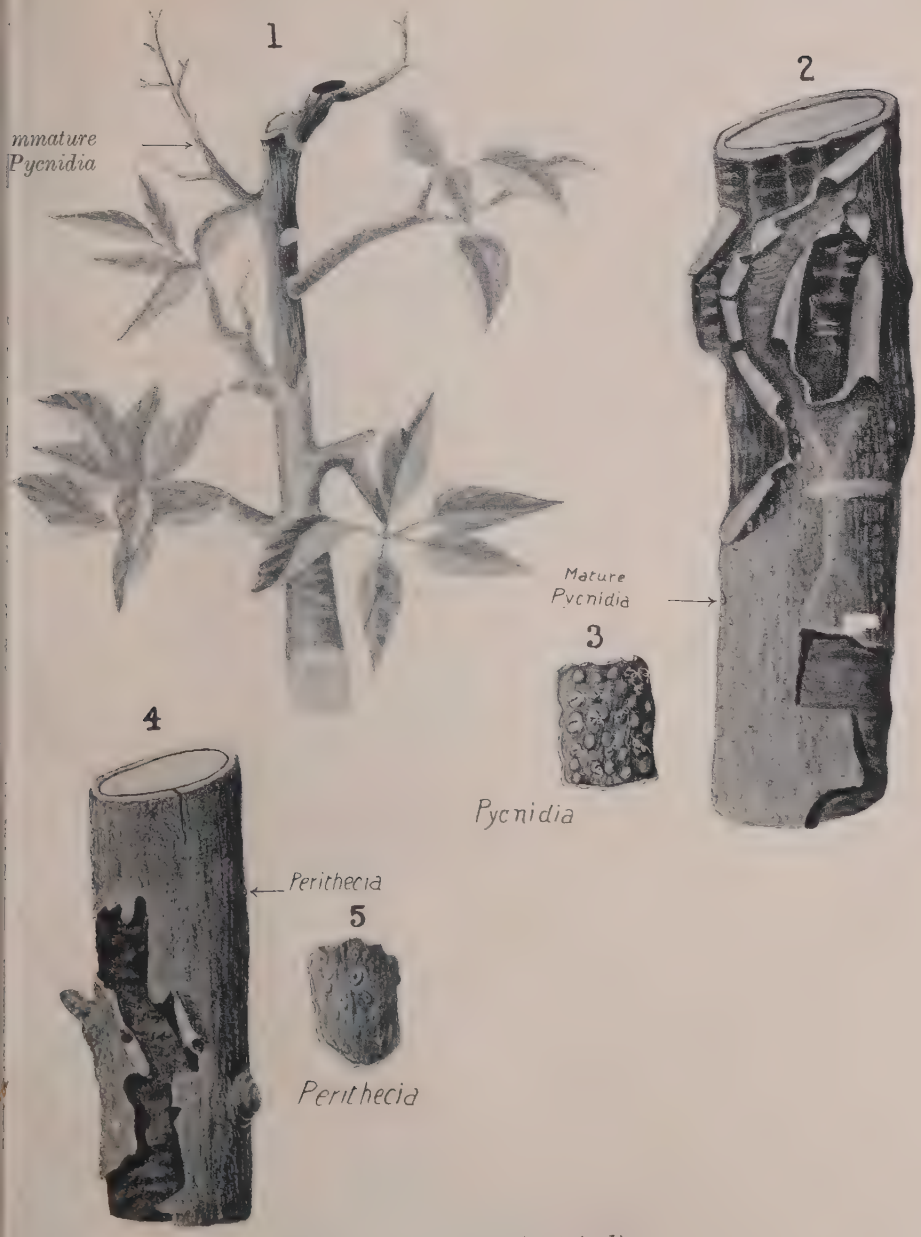
(With Plates X-XIV)

A SERIOUS disease of apple stem caused by *Botryosphæria ribis* Gross and Dugg. was recorded for the first time in India in August 1934 in the Government Orchard, Chaubattia (Kumaun), and a short note regarding the disease was given in the Annual Report of the Hill Fruit Research Scheme, Chaubattia for the year 1934-35. The specimen was sent to Mr Ashby, the Director of the Imperial Mycological Institute, Kew, who identified it as *Botryosphæria ribis* Gross. and Dugg. and he enquired whether the fungus in culture formed a red colour on starch or not, which the parasitic strains of *B. ribis* were known to produce. Since it produced this colour on starch in cultures, the fungus proved to be identical with *B. ribis*. This fungus has had a great variety of names applied to it in its different stages. The ascogeneous stage is best known in Europe under the name of *Botryosphæria Berengerians* de Not. In America it has been frequently called *Botryosphæria fuliginosa* (M+N) E & E. The occurrence in the Hudson Valley of a destructive blight or wilt of currants was first described by Fairchild [1891] and ascribed to a 'sterile' fungus. The importance of *Botryosphæria ribis* as a pathogene of currant and gooseberry was demonstrated by Grossenbacher and Duggar [1911]. They described the perfect stage as *B. ribis*. The imperfect stage common on many hosts is a *Dothiorella*. Putterill [1919] described a canker of apple trees in South Africa, which was caused by a fungus closely resembling *Botryosphæria ribis*. He called it *Botryosphæria mali*, the difference between it and *B. ribis* being in the width of asci and in the size of the stroma. Recently Stevens and Jenkins [1924] have shown that the fungus occurs on horse chestnuts and is parasitic on roses causing canker on the stem and sometimes killing the whole canes. An exhaustive history of the fungus and its host range is given by Smith [1934] who found the fungus to have a wide host range, including at least 34 genera and 20 families of plants, one of which is the apple. Birmingham [1924] recorded *Dothiorella mali* as causing a stem disease of apples in Australia. *Botryosphæria ribis*, thought to be the perfect stage of *D. mali* was found to cause rotting of apples by Fenner [1925]. Hopkins and Bacon [1938] recorded this disease on apple stem in Southern Rhodesia.

Symptoms of the disease

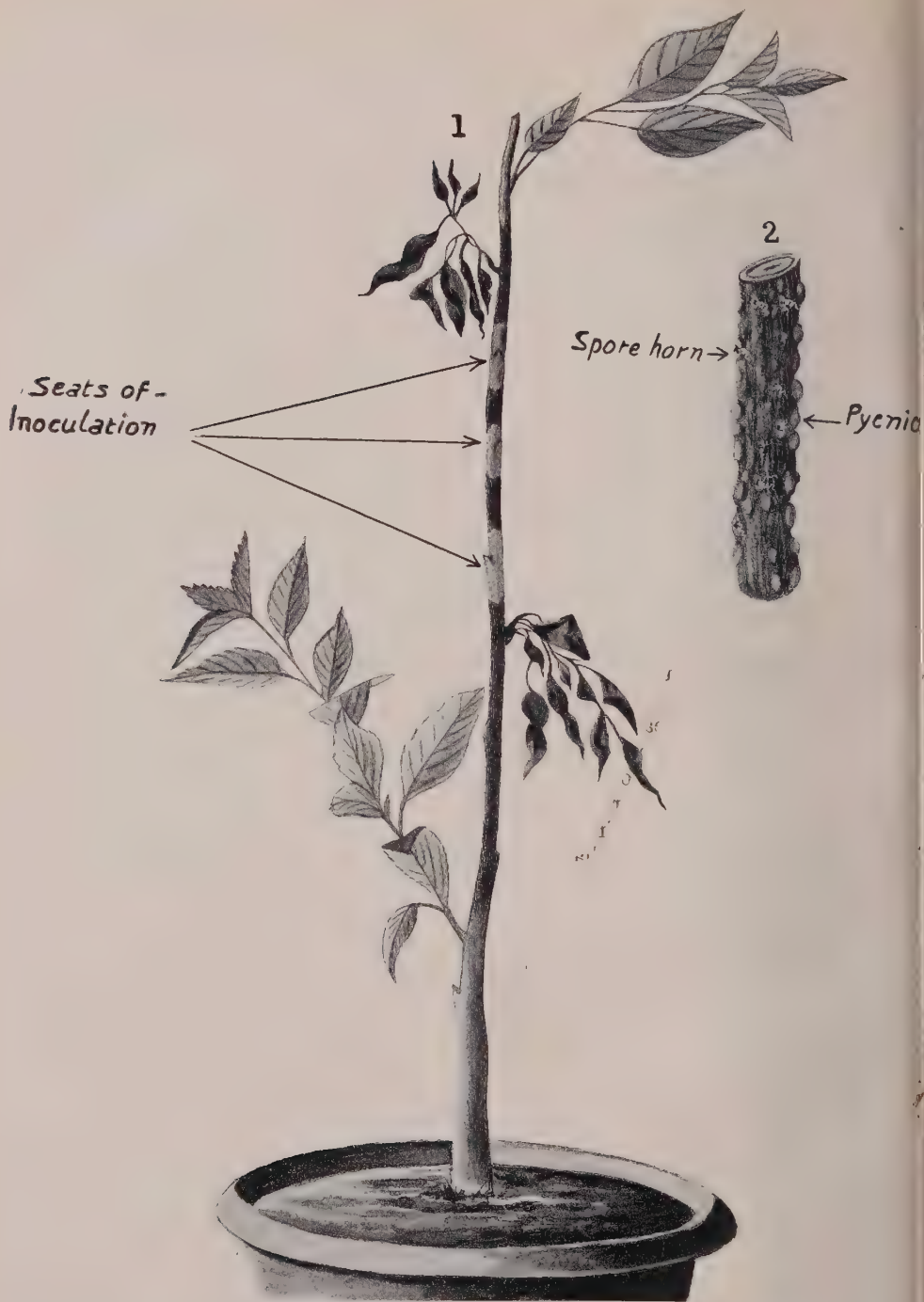
The disease starts from the pruned surface of twigs and stems and proceeds downwards causing a type of die-back (Plate X, fig. 1). The upper limbs of the apple trees are more liable to the attack. It causes a loosening

STEM-BROWN CAUSED BY *Botryosphaeria ribis*



1. Stem-brown disease on a young shoot ($\times\frac{1}{3}$)
2. Stem-brown disease on old shoot showing pycnidia ($\times 1\frac{1}{3}$)
3. Pycnidia enlarged ($\times 2\frac{2}{3}$)
4. Stem-brown disease on an old shoot showing perithecia ($\times 1\frac{1}{3}$)
5. Stem-brown disease on perithecia enlarged ($\times 2\frac{2}{3}$)

PYCNIDIAL STAGE OF *Botryosphaeria ribis*



1. One-year-old plant of Esopus Spitzenberg artificially inoculated at three places ($\times\frac{1}{4}$)
2. An enlarged portion of the infected stem showing pycnidia 'B' type with spore horns ($\times$

e bark which becomes papery and brown and rolls outwards (Plate X,). On removing the bark, the wood is found to be stained dark brown olour and fissured both horizontally and longitudinally (Plate X, fig. 2). A ined attack of the fungus and *Coniothecium chomatosporum* Corda, which d another similar disease, is often found to be present in the cankered . The disease is noticed usually by the fourth week of April and is in most virulent form by the middle of May. In old herbarium specimens idia and perithecia are met with. Perithecia are rarely found in nature. The mycelium of the fungus is found right up to the wood and is dark n in colour, closely septate tending to form chlamydospores. The ing bodies, especially pycnidia of simple type, are formed just outside cork-forming layer which is depressed by their growth. The primary ex is raised to form marked protuberences. Compound pycnidia form ll globular sclerotial bodies between the phellogen and outer cortical nchyma of shoots and stems.

Morphology of the fungus

Pycnidia

Two types of pycnidia are met with in the old diseased specimens of the le stem. For convenience these two types will be referred to in this paper pycnidia-A and pycnidia-B.

Pycnidia-A

They are very minute structures dotted all over the stem. Their con-tacles are sclerotioid, immersed, crowded with distinct ostioles in the ture stage and measure 0·25-0·5 mm. There is a small stroma ich is sometimes confluent. The central core of the conceptacle remains solid pseudoparenchyma of thick-walled, soft cells, and around this in the aline part of the stroma irregular cavities are formed (Plate XII, figs. 4 and These cavities become irregularly lined with pycnospore-mother-cells ich form within them bacillar, allantoid spores measuring 9-12$\times\pm$1μ ich are hyaline and apparently continuous. The spores seem to be set e by the dissolution of the spore-mother-cells and are thus endogenous.

The pycnospores are regarded as spermatia, and all attempts to germinate em have been unsuccessful. There are some points of resemblance of ese to the filiform bodies figured by Klebhan [1933] for *Sclerophoma strobi*. his pycnidial stage of the fungus may well be termed the sclerophoma stage. hese pycinidia-A are formed in the vicinity of stromata destined to give se to perithecia. Spear [1910] also described a similar type of small, hyaline, lindrical pycnospores measuring 2-3$\mu\times$1μ which he found on the host ly and not in culture.

Similar structures were also described by Grossenbacher and Duggar 911], but they considered that these did not belong to the life-cycle of *otryosphaeria ribis*. The spores failed to germinate. Tulasne and Tulasne 863] described and figured a similar stage for their *Dothiorella melanops*, w usually called *B. melanops* (Tul.).

Pycnidia-B

In nature pycnidia-B are found in greater abundance than pycnidia. They are minute, osteolate bodies (Plate X, fig. 3) and at times give out spo horns light pink in colour. They are either simple or compound stylospo form (*Dothiorella*) and are borne in the same or similar stroma as the p thecia.

Pycnidia-B are either single or in groups of two to six, globo black, erumpent, ostiolate having a thick wall (Plate XII, fig. 1). Th measure 126-394 × 114·8-210μ ; the average size being 220·7 × 166·2 The conidiophores are small, unbranched, hyaline, bearing pycnospores the tip. The pycnospores are fusoid to oblong, elliptical, hyaline to s hyaline, unicellular and measure 9·1-25·6 × 5·6-7·7μ ; average 17·5 6·8μ (Plate XII, figs. 3a-3o). These pycnospores germinate readily tap water within 8-12 hours and send out germ tubes from either end (Pla XII, figs. 6a-6f).

PERITHECIA

The perithecia are not so commonly met with in nature as the pycnid They are round, top-shaped bodies with papillate ostioles (Plate X, fig and 5). They either occur singly or in groups of two to eight (Plate X figs. 1 and 2). The stroma are black, more or less pulvinate, and mea from 0·5 to 5 mm. in diameter. The perithecia are sometimes interspe among pycnidia. The perithecia measure 140·0-252 × 127·4-280 average 190·7 × 192·0μ. The asci are clavate, eight spored, hyaline measure 36·4-112·0 × 14·0-18·9μ ; average 77·5 × 15·4μ (Plate X figs. 3a, 4 and 5a-5d). The ascospores are biserate in arrangement, un cellular, hyaline, fusoid, elliptical to ovoid (Plate XIII, figs. 6 and 7a 7d and measure 11·9-28·00 × 8·4-12·6μ ; average 20·2 × 10·7μ. Th paraphyses are present and are filiform. The ascospores germinate in t water at room temperature in 10-14 hours throwing out germ tube from either end. (Plate XIII, figs. 8a-8d). Affected pieces of apple twi bearing pycnidial structures were kept immersed in the snow for one mon and, when examined in March, were found to contain mature and immatu perithecia. What part the perithecia play in the spread of the disease i difficult to say, but at any rate there is clear indication that old affec twigs of apple bearing pycnidia if buried in the winter snow will undoubted be a potential source for the spread of the disease in the following spring.

CULTURAL CHARACTERS

The cultural studies of the three isolates of *Botryosphæria ribis*, no. XX (from single pycnospore), St-Br (from single ascospore) and 123 (from Holl and (Plate XIV, figs. 1 and 2) were carried out in detail on three media, Czapek agar, potato-dextrose agar and Brown's starch synthetic agar.

Linear measurements of growth

All the cultures were grown in petri dishes of equal size and the amoun of medium in each was 10 c.c. Each treatment was replicated six time and the four measurements of each of the colonies were taken. All th petri dishes were kept at a constant temperature of 30°C. in an incubator.

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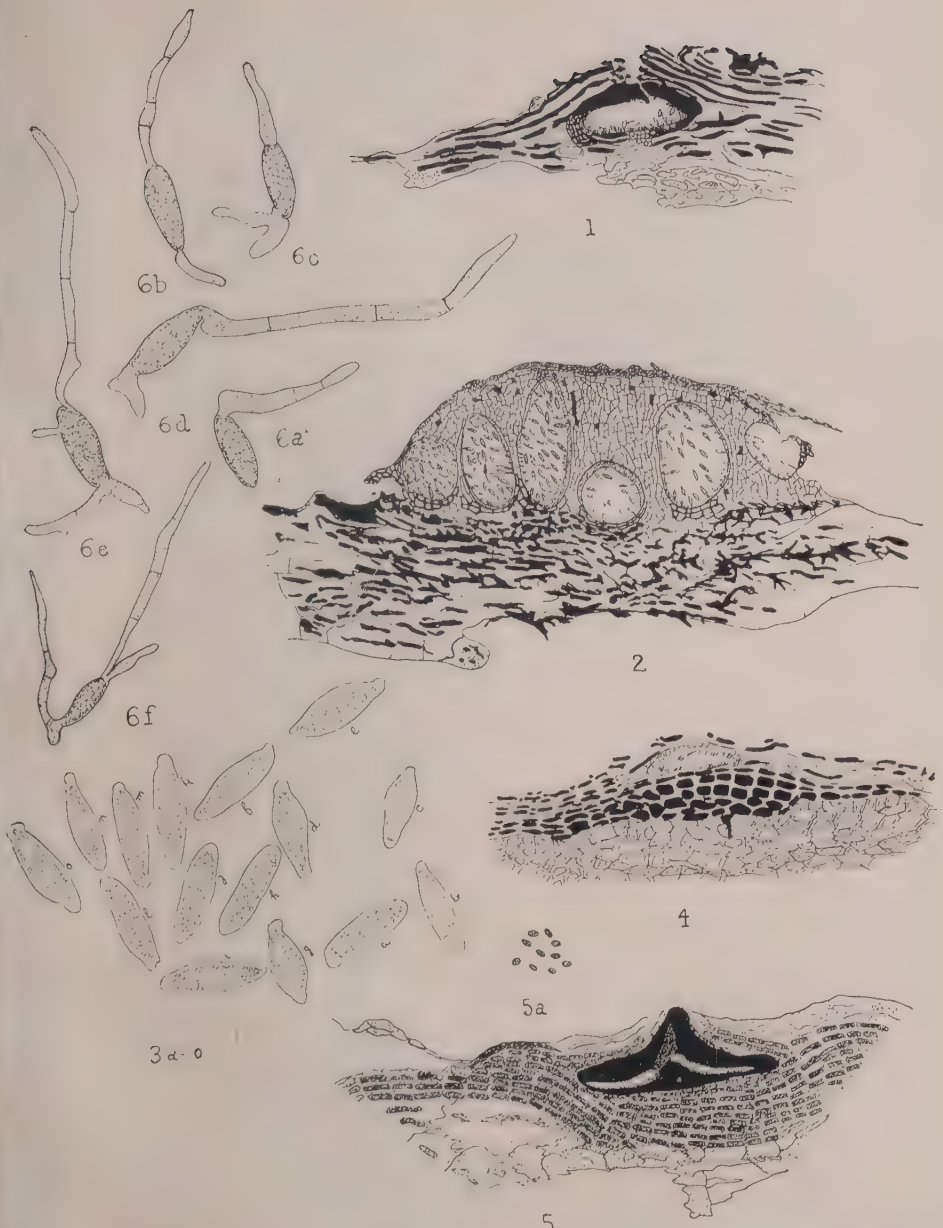
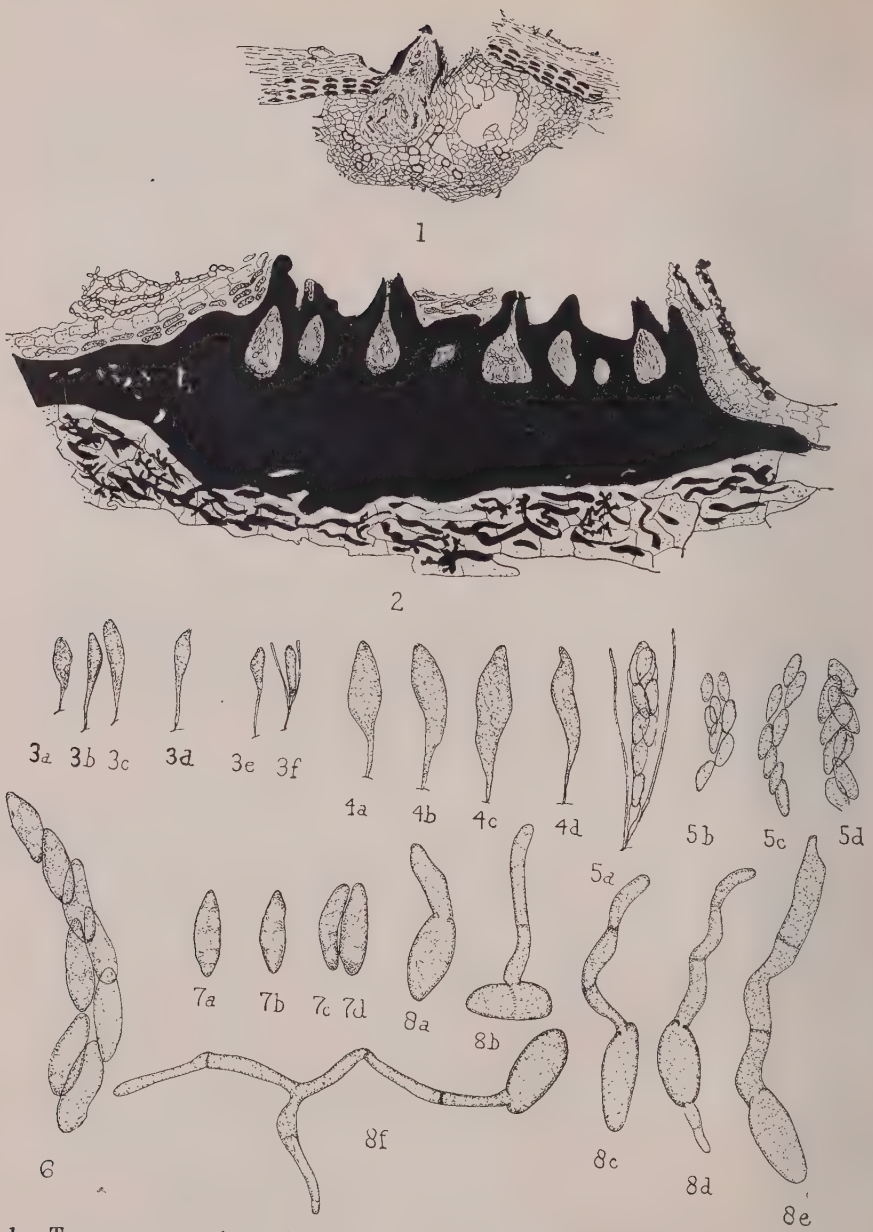


1. Transverse section of bark of apple stem showing single pycnidia ' B ' type (Dothiorella) (×107); 2. Transverse section 8μ thick of bark of apple stems showing pycnidia ' B ' of the compound stylosporic form (×107); 3*a*-*o*. Pycnospores from pycnidia ' B ' type (×1,066); 4. Transverse section of bark of apple stem showing pycnidia ' A ' type (Sclerophoma type) (×107); 5. Transverse section 8μ thick of bark of apple stem showing pycnidia ' A ' type (Sclerophoma type) (×107); 5*a*. Pycnospores from Pycnidia ' A ' type (×1,066); 6*a*-6*f*. Pycnospores ' B ' germinating (×1,066)



1. Transverse section of bark of apple stem showing perithecia (×107); 2. Transverse section of bark of apple stem showing group of perithecia (×107); *3a-3f.* Immature asci (×480); *4a-4d.* Immature asci (×1,066); *5a-5d.* Mature asci with ascospores (×480); 6. Eight ascospores (×1,066); *7a-7d.* Ascospores (×1,066); *8a-8f.* Ascospores germinating (×1,066)

It was noted that the isolate XXI grows best on Brown's starch synthetic agar, the isolate St-Br, on Czapek's agar and the isolate 123 on potato-dextrose agar. Thus all the three isolates differ from each other as far as the linear rate of growth of the cultures is concerned.

Macroscopic and microscopic characters

Macroscopic and microscopic characters were also noted for the three isolates. All the isolates differ in macroscopic and microscopic characters.

No pycnidia or perithecia were formed by any of these isolates in dark at a temperature of 30°C., but in light, at room temperature, the strain XXI formed pycnidia of ' B ' type on potato-dextrose agar only, while the isolate St-Br produced them in all the three media. Photographs of the three isolates growing on potato-dextrose agar are given in Plate XIV, figs. 1a-1c and the paired cultures in petri dishes are shown in Plate XIV, figs. 3a and 3b.

Cultural studies of the saltants

A saltant appeared in two culture flasks of the local strain No. XXI (Plate XIV, figs. 2a and 2b). They were given the numbers XXIa and XXI aI. They were isolated and grown at 30°C. on Brown's starch synthetic agar, potato-dextrose agar and cornmeal agar for comparison of cultural character with the parent strain No. XXI and also with the strain St-Br. All the cultures were kept in the dark. The principal difference was found to be in the rate of their linear growth which was faster than the parent, but slower than the isolate St-Br. On cornmeal agar and potato-dextrose agar both the saltants produced more broad and distinct zones than the parent isolates. None of them showed zonation on Brown's medium.

Inoculation experiments

Two isolates of the fungus were taken. One of the strains numbered XXI was isolated from diseased apple twigs bearing pycnidia-B in bacto-agar from the growth of a single germinated pycnospore. The other strain numbered St-Br was isolated from a single ascospore.

The two isolates differ from each other in cultural characters. They both produce the dothiorella stage but no perithecia. A third foreign isolate of *Botryosphæria ribis* received from Central Bureau Schimmelcultures Baarn (Holland) which was numbered 123 did not produce even pycnidia but remained altogether sterile. All the three strains caused chromogenesis of starch in light.

For establishing the pathogenic characters of the fungus the following experiments were carried out :—

Entry of the fungus through injured surfaces

In April 1937, 12 plants of Esopus Spitzenberg grafted on seedling stocks (age of the graft was one year) were selected. In all cases the upper portion of the stem was injured aseptically at three places, and the inoculum was placed over the injury which was then covered over with wet absorbant cotton and finally with cellophane bags (Plate XI, figs. 1 and 2). On the

lower portions of the stem the inocula were placed at three uninjured places and similarly covered. Thus we have the following arrangements :—

1. Plants A, B and C inoculated with culture No. XXI
2. Plants D, E and F inoculated with culture No. St-Br
3. Plants G, H and I inoculated with culture No. 123
4. Plants J, K and L uninoculated controls

All the inoculated and control plants were kept inside a glass cage the air of which was kept constantly humid. After about a month only the injured spots were observed to have taken the infection, while the uninjured ones and the controls remained unchanged.

The inoculated portion at first becomes depressed and becomes light brown in colour. The area of the stem below and above the inoculated portion also turns light brown, its bark becoming thin and papery. In advanced stages the whole of the infected stem turns dark brown and gets studded with innumerable pycnidia which when mature give out light pink spore horns (Plate XI, figs. 1 and 2). They were all B type of pycnidia, belonging to dothiorella stage of *Botryosphæria ribis*. Pycnidia-A did not appear in any of the infected portions. Perithecia were observed the following year (in December 1938). The progress of infection in all cases was very slow.

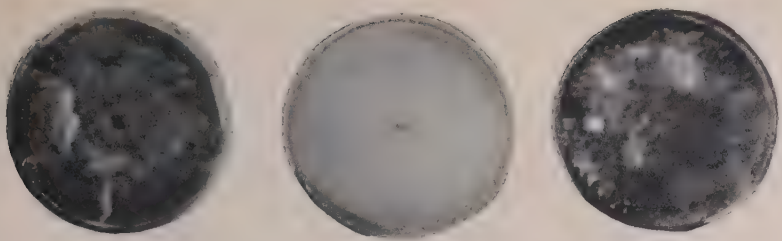
Cross-inoculation experiments

Isolate No. XXI was used in the cross-inoculation experiment. The six immature twigs of each of the six pear, peach, apricot and chestnut plants seedling stock (one year old) were cut aseptically with a pair of pruning scissors, inoculated with the mycellium of the fungus and covered over with cellophane bags. In the control, a drop of sterilized water was used instead of the culture. For the sake of comparison the culture of isolate XXI was inoculated on six immature twigs of apples in six plants. All the plants were kept inside a big glass cage and the inside of the cage was kept humid by spraying with water from time to time. The experiment was carried out on April 1938 and the infection was visible after a fortnight in all the inoculated twigs. In each case the fungus was reisolated on oatmeal agar and resembled the isolate culture in all respects. Thus it was proved that the strain No. XXI of *Botryosphæria ribis* Gross. and Dugg. could easily infect through injured surfaces of twigs of pear, peach, apricot and chestnut. In some cases pycnidia-B appeared on the affected areas of the inoculated twigs.

Sources of infection

It was observed that on the already infected shoots pycnidial structures developed by the beginning of April but mature dothiorella type was not found till later. Mature pycnidial structures were only met with in the upper portion of diseased twigs, the lower portion having only immature pycnidia. In the latter part of May, and early June immature perithecia appeared in large numbers among the pycnidia. The dothiorella type of pycnidia, which was more numerous later on in the season continued to ooze out pinkish spore horns till the month of July. Ascospores appeared in June and were copious during the middle and later part of July. Field observations have shown that fresh infections through injured uncallused surfaces of stem and

XXI 123 St-Br.

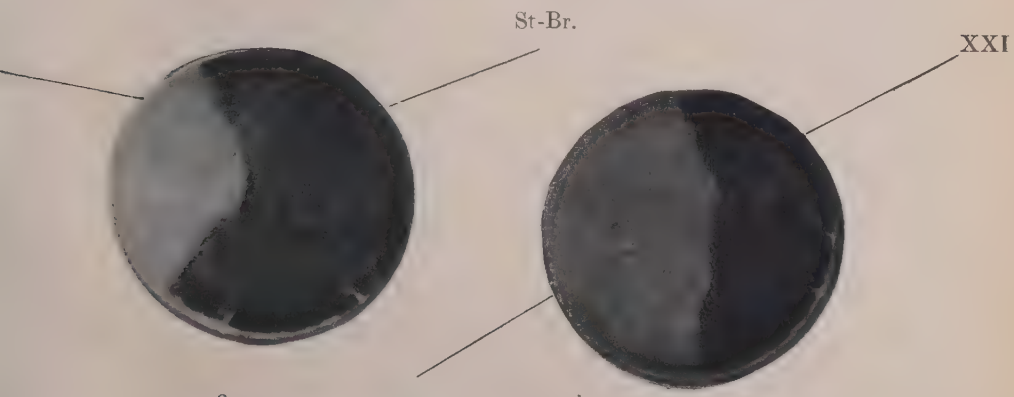


1*a* 1*b* 1*c*

Cultures No. XXI, St-Br and 123 growing on potato dextrose agar at 30°C. (3 month's old)

2*a* 2*b*

2*b*. Cultures No. XXI showing white patches of saltant No. XXIa (The culture was growing on ricemeal agar at room temperature)



3*a* 123 3*b*

3*b*. Paired culture of No. XXI and 123 and St-Br. on Czapek's agar at 30c. (18 days' old)

gs occur in June and July when the spores were abundantly produced. The diseased areas became prominent in the following season. The spores emed to be carried by rain water only. What part, if any, insects play in l dissimination of spores was not observed. The pruned diseased twigs d stems left in the orchards also serve as a potent factor in the fresh infections.

Methods of control

As the fungus can only enter through the cut pruned surface of the apple m, any suitable paint capable of preventing the entry of the fungus will an effective method of controlling the disease.

Experiments carried out in 1938

In 1938 a control experiment was started to find out a suitable paint for vering the pruned surfaces of apple twigs as a protection against the entry the fungus. This experiment was done in two sets—one for mature twigs d the other for immature ones. For each set 12 old trees were selected at ndom spread all over the orchard.

The following six treatments each replicated six times were carried out each tree :—

(*i*) Untreated (uninoculated) control I

(*ii*) Untreated (inoculated) control II

(*iii*) Treated with red lead-copper carbonate paste followed by inoculation. (The paste was prepared with 100 c.c. of raw linseed oil and 2 oz. each of red lead and copper carbonate.)

(*iv*) Treated with red lead-Bordeaux powder paste followed by inoculation. (This paste was prepared with 75 c.c. of raw linseed oil and 2 oz. each of red lead and dried precipitate of 4 : 4 : 50 Bordeaux mixture.)

(*v*) Treated with mercuric chloride solution followed by Bordeaux paste and then inoculated (the pruned surfaces were first wetted with 1/1000 $HgCl_2$ and after it dried they were painted with Bordeaux paste). (The Bordeaux paste was prepared by mixing 4 oz. of dried precipitate of 4 : 4 : 50 Bordeaux powder with 100 c. c. of raw linseed oil.)

(*vi*) Treated with self-boiled lime-sulphur paste in raw linseed oil and then inoculated. (This paste was prepared with 4 oz. of self-boiled lime-sulphur, the proportion of quick lime and sulphur being 2 : 2 mixed in 100 c.c. of raw linseed oil.)

After the paints dried, the treated and untreated portions were inoculated ix times with the culture of the fungus No. XXI, covered over with sterilized vet absorbant cotton and then with cellophane bags.

The inoculations were repeated from the middle of April to the middle of August at an interval of a fortnight. After about a month the twigs were examined in the laboratory.

The percentage of infection and the comparison of various treatments are given in Table I. From these tables it is evident that the paste of red lead and copper carbonate in raw linseed oil was the best paint for both mature and immature twigs, to prevent infection of their pruned surfaces.

TABLE I

Comparison of different treatments (1938)

No.		Mean percentage of infection						General mean	Standard error of difference	Critical difference for significance	Whether significant by z test
		(i) Untreated and un-inoculated (control I)	(ii) Untreated and inoculated (control II)	(iii) Red lead and copper carbonate paste	(iv) Red lead and Bordeaux paste	(v) Bordeaux paste	(vi) Self-boiled lime-sulphur paste				
					(a) Immature twigs						
1	Per treatment	43·05	86·10	31·94	65·27	74·91	68·05	61·55	6·28	13·3185488	Yes $P=0·01$
2	Percentage on general mean	69·90	139·88	51·89	106·04	121·69	110·56				
3	Percentage on control I	100·00	200·00	74·19	151·61	174·00	158·07				
4	Percentage on control II	50·00	100·00	37·09	75·80	79·03	79·03				
					(b) Mature twigs						
1	Per treatment	90·27	100·00	31·94	90·27	93·04	93·04	83·09	3·77	7·3879492	Yes $P=0·01$
2	Percentage on general mean	108·64	120·35	38·44	108·64	111·97	111·97				
3	Percentage on control I	100·00	110·77	35·88	100·00	102·06	103·06				
4	Percentage on control II	90·27	100·00	31·94	90·27	93·04	93·04				

Dey and Singh [1939] found the paste of red lead with an equal amount pper carbonate in raw linseed oil to be the best for controlling the stem-ek disease of apple trees caused by *Coniothecium chomatosporum* Corda, h like the stem-brown disease always started from the pruned surfaces. Thus by using the same paint it is possible to control both the stem-k and stem-brown diseases of apple trees.

eriments carried out in 1940

In 1940, another control experiment was started with a view to finding whether lanoline, which is known to hasten the formation of callus, is effective in warding off the disease. Both mature twigs, $\frac{1}{2}$ in. thick, and nature twigs of the apple variety Jonathan were used. Twenty-four s, 12 for mature twigs and 12 for immature ones, were selected at random he orchard. The following six treatments each replicated six times were ried out in each of the 12 trees :—

(*i*) Untreated and uninoculated (control I)
(*ii*) Treated with lanoline and uninoculated
(*iii*) Treated with lanoline and inoculated
(*iv*) Untreated and inoculated (control II)
(*v*) Treated with lanoline mixed with an equal amount of red lead and copper carbonate and inoculated
(*vi*) Treated with red lead and copper carbonate in equal amounts mixed with raw linseed oil and inoculated

After the paints dried the treated and untreated portions were inoculated th the culture of the fungus No. XXI, covered over with wet absorbant tton and then with cellophane bags. Six inoculations were done after ervals of a fortnight. Twenty days after the last inoculation the twigs re examined in the laboratory.

The mean percentage of infection and the comparison of different treat-nts are given in Table II.

The following conclusions were arrived at :—

1. Treatment v (a paste of red lead and copper carbonate in equal amounts in lanoline) is significantly better than all the other treatments
2. Lanoline alone (treatments ii and iii) is unable to stop the entry of the fungus
3. Treatments i, ii, iii and iv are not significantly different from one another
4. Treatment *vi* (a paste of red lead and copper carbonate in raw linseed oil) is significantly better than treatments i, ii, iii and iv :—
   (*a*) v>i=ii=iii=iv
   (*b*) vi>i=ii=iii=iv
   (*c*) v>vi

Discussion

This disease is primarily the disease of currants and was first noticed by irchild [1891] in the Hudson Valley. In 1896 the currant growers of arlboo brought the disease to the attention of the New York Agricultural

TABLE II

Comparison of different treatments (1940)

No.		Mean percentage of infection						General mean	Standard error of difference	Critical difference for significance	Whether significant by z test
		(i) Untreated and uninoculated (control I)	(ii) Treated with lanoline and uninoculated	(iii) Treated with lanoline and inoculated	(iv) Untreated and inoculated (control II)	(v) Treated with lanoline mixed with red lead and copper carbonate in equal amounts and inoculated	(vi) Treated with red lead and copper carbonate in equal amounts in raw linseed oil and inoculated				
					(a) Immature twigs						
1	Per treatment	97·22	98·61	100·00	98·61	38·88	58·71	82·17	5·53	$5·53 \times 1·95996 = 10·385788$	Yes $P = 0·01$
2	Percentage on general mean	118·31	120·00	121·69	120·00	47·31	72·66				
3	Percentage on control I	100·00	101·42	102·86	101·42	39·99	61·41				
4	Percentage on control II	98·59	100·00	101·41	100·00	40·45	62·27				
					(b) Mature twigs						
1	Per treatment	98·61	95·85	97·22	100·00	29·08	45·83	77·76	6·82	$6·82 \times 1·95996 = 13·3669272$	Yes $P = 0·01$
2	Percentage on general mean	126·81	123·23	125·02	128·60	37·89	58·93				
3	Percentage on control I	100·00	97·18	98·59	101·41	37·91	59·76				
4	Percentage on control II	98·61	95·83	97·22	100·00	29·08	45·85				

ation. At this time Durand of Cornell University was investigating a milar currant disease found in western New York [Durand, 1897]. *Nectria innabarina* was named as the cause of the disease. In 1899 extensive obser-ations carried out by Grossenbacher and Duggar [1911] established the fact hat the currant blight occurring in the Hudson Valley is not caused by *ectria cinnabarina* but by Fairchild's [1891] 'sterile' fungus. In 1907 e thorough study of the fungus was completed by Grossenbacher and Duggar 911]. Putterill [1919] described a canker of apple trees in South Africa d named the fungus *Botryosphæria mali* which differed from the currant ngus, *B. ribis*, in the width of its asci and the size of the stroma. Shear, tevens and Wilcox [1925] believed that this fungus was not different from *ribis*.

Fenner [1925] described a fruit rot of apples caused by *B. ribis*. Birming-m [1924] described a canker of apple trees in South Wales. In 1934 Smith 939] described the host range of the fungus and found that it included a st of 34 genera and 20 families of plants. This is a fungus of the type figured nd described by Tulasne and Tulasne [1863] as *Dothidea melanops*, later n made into the type species of a new genus *Melanops* by Nitschke [1869]. esati and Notaris [1863] founded another new genus *Botryosphæria* in which ne forms like *D. melanops* were included, along with some pharagmosporic orms. It is claimed, however, that since *Gibberella pulicares* (Fries) Sacc. ay have been taken as a type species of *Botryosphæria*, Nitschke's *Melanops* 869] should be used for forms like the original *Dothidea melanops* Tul. owever, Saccardo [1892] re-defined the limits of the genus *Botryosphæria* by cluding the forms which develop septate spores. Even though the generic ame *Melanops* may replace *Botryosphæria* for fungi of this type because pparently the type species of the later was subsequently transferred to *ibberella*, it seems unnecessary to revive an unused name for the isolated se involved in the investigation.

The presence of the two types of pycnidia and one type of perithecia in he life-history of the fungus makes the dissimation of the spores very active n causing primary infections. The comparative measurements of fructifica-ion from different hosts by various workers are given in Table III. From hese comparative data it will be seen that the Indian strain very closely esembles *Botryosphæria ribis* of Gross. and Dugg. The slight differences in he measurements of fructifications and spores may have been due to environ-nental differences.

Summary

The stem-brown disease of apple is caused by *Botryosphæria ribis* Gross. nd Dugg., and usually starts from pruned surfaces and proceeds downwards ausing a type of die-back.

Two types of pycnidia are found. Pycnidia of the *Sclerophoma* type are mall and the pycnospores are bacillar, allantoid, and do not germinate. he other type of pycnidia are of the *Dothiorella* type, either single or in groups, nd the pycnospores are fusoid to oblong, elliptic, hyaline to subhyaline, nicellular and germinate in tap water in 8-12 hours. The perithecia are ound rarely in nature. These are either single or in groups of two to eight,

TABLE III

Comparative sizes of fructifications of Botryospæria ribis *from different hosts in different countries by different workers*

Fungus	Host	Locality	Author	Pycnidia (μ)	Pycnospores (μ)	Perithecia (μ)	Asci (μ)	Ascospores (μ)
Botryosphæria ribis Gross. and Dugg.	Currant (*Ribis vulgare*)	Hudson Valley, U. S. A.	J. G. Grossenbacher and B. M. Duggar [1911]	175—250 wide	18—31×4·5—8	175—250 wide	80—120×17·20	16·23×5—7
Botryosphæria mali	Apple (*Pyrus malus*)	South Africa	V. A. Putterill [1919]	250×190	22·4×4·8	235×142 wide	96×13	19·2—19·5×6·5—8
Botryosphæria sp. (Indian strain)	Apple (*Pyrus malus*)	India, Chaubattia U. P., Kumaun Hills	U. B. Singh [1934]	126·0—294×140—199; Av. 220·7×166·2	9·1—25·9×6·3—7·7; Av. 17·52×6·77	140·0—252×130·2—280; Av. 192·0×190·7	36·4—112·0×14·0—18·9; Av. 77·49×15·39	11·9—28·0×8·4—12·6; Av. 20 1×10·7
Botryosphæria ribis	Currant (*Ribis vulgare*)	From various localities of U. S. A.	N. E. Stevens and A. E. Jenkins [1924]	...	14—31·5×4—7·5 mostly 18·23×5·7	...	...	14 27×5 10 Av. 16·23×6 8

shaped with ostioles. The asci are clavate, eight spored and hyaline. ascospores are biseriate, unicellular, hyaline, fusoid, elliptical to egg-ped. Paraphyses are present and are filiform. These ascospores germinate dily in tap water in 10-14 hours.

Two isolates of the fungus were taken, one from a single pycnospore, other from single ascospore. A third foreign strain was also included in study. The cultural studies of the three strains were carried out on pek's agar, potato-dextrose agar and Brown's starch synthetic agar, and was found that the strain XXI grew better on Brown's starch agar and the in (St-Br) grew best on potato-dextrose agar. The macroscopic and roscopic observations were also recorded.

All these three strains were found to cause infection of apple twigs through h injured and uninjured surfaces. The progress of infection in all cases very slow.

One of the three strains was cross-inoculated on cut twigs of pear, apricot, ch and chestnut and was found to infect them.

The cultural studies of the two saltants and the two parents were carried on three different media—Brown's starch synthetic, cornmeal agar and ato-dextrose agar. The strain St-Br grew best in all three media ; one he saltants XXIa grew better than the parent and other saltant XXIa I, w best in all the three media.

Pycnospores from the dothiorella type of pycnidia and, to a lesser extent, ospores carried by water serve as the potent factor for fresh infections. sh infections take place from May to July.

A mixture of red lead and copper carbonate in equal amounts in raw eed oil when applied as a paste on the cut pruned surfaces of apple stem ctively controls the disease.

A paste of red lead and copper carbonate in equal amounts in lanoline is nificantly better than a paste of red lead and copper carbonate in equal ounts in raw linseed oil.

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CITRUS ROOTSTOCK TRIALS IN THE PUNJAB

I THE VIGOUR OF YOUNG TREES OF SWEET ORANGE, MANDARIN AND GRAPEFRUIT AS INFLUENCED BY DIFFERENT ROOTSTOCKS

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(With Plates XV-XVII and one text-figure)

THE most economic and widely accepted method of propagating citrus fruits both in India and elsewhere is by shield-budding a selected scion variety on a suitable rootstock. The success of the combination is markedly affected by both soil and climate, since it is well known that a given rootstock, which is satisfactory in one country or locality, may be a complete failure in another [Brown, 1920 ; Powell, 1930 ; Toxopeus, 1937 ; Webber, 1925]. Furthermore, certain rootstocks are known to exert a considerable influence on the vigour, cropping, etc. of the scion varieties budded or grafted on them [Brown, 1920 ; Bonns and Mertz, 1916 ; Batchelor and Webber, 1939 ; Hatton, 1927 ; 1928-29 ; 1931 ; 1935 ; Hodgson and others, 1937 ; Quinn, 1932 ; Rogers, 1926 ; Rogers and Vyvyan, 1928 ; Singh , 1936 ; Tydeman, 1926-27 ; Webber, 1934 ; Richards, 1938], and certain scions under appropriate conditions show an equally noticeable effect on certain rootstocks [Amos and others 1930 ; Brown, 1920 ; Halma, 1934 ; Hass and Halma, 1929 ; Hatton, 1923 ; 1927 ; Hodgson and others, 1937 ; Roberts, 1929 ; 1931 ; Swarbrick, 1927 ; 1931 ; Tukey and Brase, 1933 ; Webber, 1919 ; Wormald and Grubb, 1924 ; Vyvyan, 1930]. Recent rootstock investigations, especially in England and America, where considerable work has already been carried out on the problems arising directly from the twofold structure of a fruit tree, have tended to emphasize the need for standardized material for all types of investigation. In these countries the growers are at a much greater advantage than their contemporaries living in more backward places, for they will now plant only such scion-stock combinations as have been proved suitable to their conditions.

In our own country, excepting the preliminary work of Brown [1920], Shrivastava [1920] and Prayag [1920], little experimental evidence is available concerning rootstocks for use with the various cultivated species of citrus. Growers have vague and varied impressions of the so-called ' rootstock effect ' and it is, therefore, not surprising that all sorts of rootstocks are in common use. The prevalence of low yields, inferior fruit quality and the early decline

of large number of trees is due in a large measure to the promiscuous use o miscellaneous rootstocks by Indian nurserymen.

The available evidence on rootstock investigations points to the fact tha the performance of a budded or grafted plant is an expression of the reciproca effect of the two symbionts. On this basis rootstocks have been designated as vigorous or dwarf, etc. but since the vigour of different scion varieties and species on the same rootstock is known to be different [Hatton, 1935 Roberts, 1929], the terms vigorous and dwarf must be regarded as purely relative. Not only this, the recent findings of various workers [Barker, 1927 Roberts, 1929 ; Singh, 1936 ; Tukey and Brase, 1933] show that a scion variety has apparently an inherent growth capacity which it normally exhibits, a capacity which may be dwarfed very considerably but which apparently may not be increased beyond a very small amount. This conclusion leads directly to the suggestion that in all cases, where rootstock influence is a limiting factor to tree size, it is of a dwarfing character. Roberts [1929] goes even as far as to suggest a classification of rootstocks on this basis. According to him the so-called vigorous rootstocks of Hatton [1926] are really neutral since they do not, in any way, limit the free development of the scion. Dwarfing rootstocks, on the other hand, are dominant since they do not allow the scion to develop to its natural capacity.

The present study forms part of a programme of rootstock investigations designed to determine the most suitable rootstocks for sweet orange (Malta), mandarin (Sangtra) and grapefruit in the Punjab, and was carried out during the years 1937-40 upon material planted at Montgomery in February, 1937.

The period of study covers only the vegetative phase of these trees. In view of the fact that growth responses may considerably change during development and maturity, it is essential that the evidence of rootstock influence concerning the two phases of the life of fruit trees should be discussed separately, and it is on this account that the results to date are reported at this stage.

Experimental material

Preparation of the material

Nearly all the important varieties of citrus rootstocks were collected from various parts of India and Ceylon, partly to prepare the material for rootstock investigations and partly to make an enquiry into the distribution of different varieties of citrus so as to report on their nomenclature. The latter work will be dealt with in a separate communication.

Seeds as well as cuttings of the rootstock varieties were, as far as possible, obtained from the same parent tree in each case. Both seeds and cuttings were planted at the same time, viz. September 1932. Both the apogamic seedling rootstocks as well as those that could also be propagated by the rooting of stem cuttings were budded over in August 1935, at a uniform height of nearly 9 in. from the ground level, which is the practice commonly followed in the Punjab. It is obvious from the foregoing that the rootstocks, whether raised from seed or by the rooting of stem cuttings, were of uniform age at the time of budding, but it by no means follows that they were of the same vigour. Even within any given rootstock, the progeny differed considerably with respect to height and thickness. However, only fairly uniform

dividuals in each lot were selected for budding and the variants were dis-rded as advocated by Webber [1920 ; 1932]. As a rule, nearly all the vrieties made growth of sufficient vigour to allow of the budding operation, t some rootstocks definitely made much better growth than others.

The experimental material was prepared according to the established rsery practice followed all over the province. Seeds were sown in raised edbeds in September 1932. The seedlings were dug up in September 33 and the uniformly vigorous ones only were transplanted in nursery-ds. The stock became fit for budding in September 1935, viz. two years ter transplanting, when uniformly vigorous seedlings were budded by a gle operator. The budded nursery trees were transplanted in another ece of land at Lyallpur in September 1936 before finally planting the same the orchard in February 1937 at Montgomery—a place about 200 miles om Lyallpur.

The transplanting of budded trees in the nursery, prior to final planting the orchard, is not usually practised. But, in this particular case, the peration was considered necessary.

Three scion varieties, namely Malta local (*Citrus sinensis* Osbeck), Sangtra cal (*C. nobilis* var. *deliciosa* Swingle) and grapefruit (*C. maxima* var. *Uvacarpa* errill and Lee) were budded in August 1935 on to each of the several root-ock varieties propagated from seed and cuttings. Although the preparation f genetically identical material could have been advantageously effected by lacing scion buds gathered from a single tree on to carefully selected apogamic edlings [Webber, 1932 ; Imp. Bur. Fruit Production Tech. Com., 1932], yet lonal vegetatively raised material was also used in order to answer such uestions of practical and economic importance as (1) Will the vegetatively ropagated rootstocks differ from the apogamic seedlings in their influence on he scion variety notwithstanding the similarity of their genetic build-up ? If o, how and to what extent and degree ? (2) How will the variability in the wo sets of material as regards vigour, etc. determined at planting time com-are later in the life-history of the experiment ? A further point of particular nterest is the utility of the various rootstocks for Malta, Sangtra and grape-ruit, under conditions similar to those where the experiments are conducted his will be determined by investigations into the influence of rootstocks on cions as regards (*a*) growth and vigour, (*b*) productivity, (*c*) fruit quality, (*d*) esistance to diseases and (*e*) longevity. Information regarding all these oints will be made available when the data collected is sufficient to justify heir publication.

Description of the material

As stated before, the experimental material broadly consists of two sets f groups. In one set, the three scion species are budded on to the several ootstocks raised from seed ; in the other set, the same three scion species are udded on to vegetatively propagated rootstocks. With a few exceptions, he rootstock varieties of the experimental material are the same in both the ets. For convenience of reference these sets will be designated as set A nd set B. Set A constitutes the three scion-stock groups prepared by bud-ing three scion species on several rootstocks propagated from seed, and et B includes the other three groups prepared by budding the same three

scion species on the rootstocks that were propagated by vegetative means. The specifying numbers allotted to the rootstocks in both sets of groups are purely arbitrary and are not based on any systematic study.

The various scion-stock combinations in sets A and B are tabulated in Table I.

TABLE I

Different scion-stock combinations under experiment

Name of scion-stock combination		No. of trees under study	
Set A.— (*i*) Malta local on rootstock No.	43	24	
Ditto	21	24	
Ditto	20	24	120
Ditto	50	24	
Ditto	9	24	
(*ii*) Sangtra local on rootstock No.	43	18	
Ditto	9	18	
Ditto	21	18	90
Ditto	20	18	
Ditto	50	18	
(*iii*) Grapefruit on rootstock No.	43	24	
Ditto	20	24	
Ditto	47	24	120
Ditto	50	24	
Ditto	9	24	
Set B.— (*i*) Malta local on rootstock No.	20	18	
Ditto	43	18	
Ditto	50	18	72
Ditto	9	18	
(*ii*) Sangtra local on rootstock No.	43	18	
Ditto	20	18	
Ditto	9	18	72
Ditto	50	18	
(*iii*) Grapefruit on rootstock No.	43	18	
Ditto	20	18	
Ditto	50	18	72
Ditto	9	18	

The material in sets A and B is planted separately in contiguous fields but the lay-out, viz. arrangement of plots, position of main water channels, block water channels and position of paths, etc. is uniform in each case.

LAY-OUT

It is evident from the foregoing section that sets A and B have each three different groups of scion-stock combinatoins, depending upon the number of scion varieties employed. There are thus in all six different groups of

xperimental material planted in six different fields. The randomized lock method, being most adaptable to field experiments in horticulture, s the one here adopted. The rrangement and distribution f different scion-stock combi- ations within the plots is ex- plained by Fig. 1. The method f lay-out of each field is the ame as shown in this figure.

A glance at the lay-out, given in Fig. 1, shows that here are seven rootstocks nder trial in set A, of which a omparative study of only five s reported in this paper. The osition of the trees on root- tocks 44 and 1, which have ot been dealt with, is shown y shaded sub-plots in the igure. These two rootstocks ave turned out to be horticul- urally the same as No. 20 (rough lemon). Thus, rough emon is represented thrice in ach replicate, whereas each of the four remaining rootstocks is represented only once in each block. With a view to keeping uniformity in the numbr of re- plications (one sub-plot to re- present each treatment in each block) it was necessary to select one out of the three identical varieties originally planted; No. 20 was selected because in set B, rootstocks 44 and 1 were not included for trial and only 20 was used.

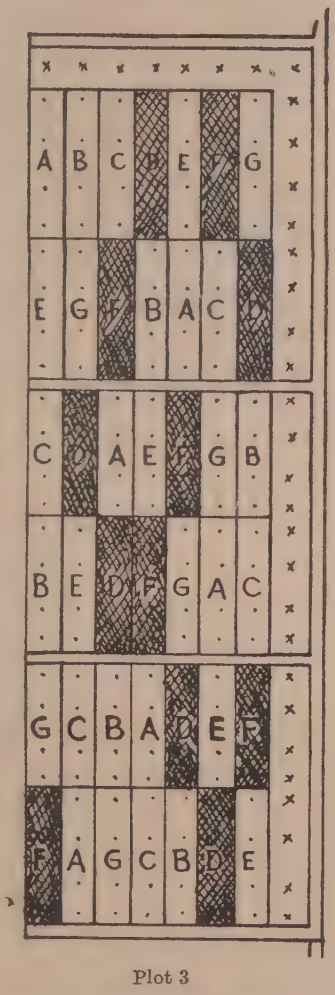

FIG. 1. The distribution of seven scion-stock combinations in six blocks in plot No. 5

A. Malta local on rootstock No. 20* B. Malta local on rootstock No. 9
C. „ „ No. 21 D. „ „ No. 1*
E. „ „ No. 43 F. „ „ No. 44*
G. Malta local on rootstock No. 50

..... Experimental trees ××××× Non-experimental trees
Water channels

*Rootstocks No. 20, 1 and 44 are found to be one and the same.

The piece of land for each experiment is divided into six blocks of similar dimensions. Thus, six replications are provided for each series of scion-stock combination. Each block in turn is divided into as many plots of equal size and shape as the number of rootstock varieties to be compared. The allocation of scion-stock combinations to particular plots was determined by drawing lots, as a result of which each combination is represented once in each block. The dimensions of the plots vary from 20 ft. × 60 ft. to 20 ft. × 80 ft. depending upon the number of trees planted. In other words, a unit of three to four trees of any particular scion-stock combination is replicated six times so that there are 18-24 trees of this in any one experiment.

The planting of all the six experimental fields follows the square system. A uniform distance of 20 feet from tree to tree and row to row is being adopted.

Due attention was given to the variability within the experimental material at the time of planting. The trees within each lot were roughly graded according to vigour and planted in such a way as to include only fairly uniform ones of all combinations in each block. There being six blocks placed end to end in each case (Fig. 1), the variability within the material is allowed for in block variance when computing the data.

Methods employed

Soon after planting the material in 1937, trunk circumference measurements of all the trees were taken at a uniform height of approximately one foot from the ground level. The places of measurement were marked with white paint so that the girth measurements could be taken at a fixed point year by year. The union of the scion with the rootstock was invariably below the place of measurement.

The girth measurements were taken again in 1938, 1939 and 1940 at yearly intervals with a view to determining the growth response during early years of the various scions growing on different rootstocks. The girth measurements serve as a measure of the vigour of the trees in these trials. The data regarding girth, for all the years, have been examined statistically by the analysis of variance [Fisher, 1934]. The differences above the 5 per cent level only are taken as significant. On the basis of the information thus gathered the various scion-stock combinations have been grouped so as to show at a glance their behaviour from year to year.

Distinguishing names of the rootstock varieties employed

The morphology and other characters of the rootstock varieties employed in this study along with others in the collection have been studied during the last two years in order to clarify their nomenclature. This work, when completed, will be published separately, but in the meantime the rootstocks under trial have been properly identified as follows:—

TABLE II

Distinguishing names of the rootstock varieties under trial

ames under ich received	Arbitrary specifying numbers allotted as referred to in this paper	Popular local names in the Punjab	English equivalents	Specific names
Mitha . .	50	*Mitha* .	Sweet lime .	*C. aurantifolia* var. Swingle
Khatti . .	20	*Jatti khatti*	Rough lemon	*C. limonia* Osbeck
Chakotra .	47	*Chakotra* .	Shaddock .	*C. maxima* Merrill
Turanj .	9	*Mokari* .	Citron . .	*C. medica* Linn.
Kharna khatta	43	*Kharna khatta*	Nil	*C. karna* Raf.
Nasnaran .	21	Nil	Nil	*C. japonica* Thumb

Beside the six rootstocks mentioned above, another apparently distinct ies, viz. *khatta* (*C. aurantium* Linn.) was also included, but on studying morphological characters it was found to be really rough lemon. It is dent that the material used as rootstocks does not include species like *rus aurantium*, *C. nobilis* and *C. sinensis*, etc. These species, especially first one, are probably indigenous to India, and may, therefore, have great sibilities as rootstocks in view of the fact that they are already in use some of the citrus-growing countries of the world [Coit, 1927 ; Hume, 1930 ; well, 1930]. In preparing further material, these species will be included well as others that are now growing in the rootstock collection plot at ntgomery. Furthermore, certain points of practical importance regarding se rootstocks are being studied in preparation to a further and more ex- nded trial of rootstock material.

PRESENTATION OF RESULTS

As mentioned in previous sections, the girth measurements of all the es constituting the various scion-stock combinations were taken annually 937-40) as an index of their vigour as influenced by the rootstocks on which ey were stem-budded. The data for 1937 relates to the behaviour of maidens at the time of planting in the orchard, that for 1938 as the behaviour of e-year old plants and that for 1940 as the behaviour of three-year old plants. ne material constitutes two sets, set A and set B. In set A apogamic seed- gs have been used as rootstocks and in set B the rootstocks used were pro- gated by the rooting of stem cuttings. The genetic composition of any rticular rootstock in both the sets is thus identical but apogamic seedlings

and rooted cuttings being physiologically different, the results of their p formance with different scions are presented separately as under :—

Scion-stock combinations of set A with different scion varieties

1. Malta local.—The mean data and significant difference at the per cent level are compiled in Table III which shows the relative size of thr year old plants of this variety as influenced by different rootstocks (Pla XV-XVII).

TABLE III

Performance of Malta local variety with certain rootstocks of apogamic orig

Year	Average circumferential measurements in cm. for root-stock numbers					General Mean	S. E.	Signi cant d erence P = 0
	43	21	20	50	9			
1937 . . .	5·08	5·63	3·55	3·35	3·61	4·25	0·23	0·7
1938 . . .	5·58	6·29	4·25	4·09	3·99	4·84	0·29	0·9
1939 . . .	9·97	8·83	8·50	7·73	6·11	8·23	0·57	1·8
1940 . . .	16·7	15·7	15·4	14·0	12·2	14·37	0·66	2·1

The performance of different scion-stock combinations has first to b examined separately for all the four years before discussing them togethe The resultant effect of the various combinations on the vigour of the scio is tested by comparing the difference between average circumferential me surement figures relating to any pair of combinations with the significa difference figure given in the last column for each year. On the basis of th comparison, the various rootstocks, differentiating themselves from one a other, are put in different groups. When certain rootstocks are found to exhib only small differences as compared with the significant limit, they are put one and the same group. The grouping of the various rootstocks, based on th statistical examination of the data given in Table III, is made as under :—

Year	Group 1	Group 2
1937 . . .	21 ; 43	9 ; 20 ; 50
1938 . . .	21 ; 43	20 ; 50 ; 9
1939 . . .	43 ; 21 ; 20	50 ; 9
1940 . . .	43 ; 21 ; 20	50 ; 9

The figures show that the above five rootstock varieties fall into tw groups even in the nursery stage. Thus, rootstocks 21 and 43 are associate with the more vigorous trees of Malta local variety, whereas the remainin rootstocks (in group 2) are associated with trees of medium vigour. The group ing of the rootstocks for 1938, viz. one year after planting, was substantiall the same except in their order of vigour within group 2. By the end of th second year of their life in the orchard, i.e. in 1939, the various rootstock still fall into two groups but their order of vigour is considerably changed Thus, rootstock 20 is now bracketed with 43 and 21 as being vigorous, and tree

FIG. 1. Local Malta on *kharna khatta*

FIG. 2. Local Malta on *nasnaran*

FIG. 1. Local Malta on *jatti khatti*

FIG. 2. Local Malta on *mitha*

:k No. 43 are now slightly more vigorous than those on No. 21. Root-50 and 9, however, remained in group 2. The behaviour of the different ocks in 1940 remained exactly the same as during 1939 and it appears ootstocks 50 and 9 may ultimately prove to be dwarfing for the Malta ariety.

Sangtra local.—The mean data and significant difference at the 5 per vel are compiled in Table IV, which shows the relative size of three year es of this variety as influenced by different rootstocks.

TABLE IV

nance of Sangtra local variety with certain rootstocks of apogamic origin

ear	Average circumferential measurements in cm. for root-stock numbers					General mean	S. E.	Signifi-cant diff-erence for $P=0{\cdot}05$
	43	9	21	20	50			
. .	4·97	3·42	3·19	2·17	2·33	3·22	0·18	0·55
. .	6·14	4·53	4·16	2·83	3·38	4·21	0·17	0·53
. .	11·77	9·34	8·61	7·26	7·96	8·99	0·30	0·94
. .	19·5	16·1	15·9	15·5	14·5	16·28	0·41	1·32

ie grouping of the various rootstocks, based on the statistical examina-the data given in Table IV above, is made as under :—

Year	Group 1	Group 2	Group 3	Group 4
937 . .	43	9; 21	50; 20	..
938 . .	43	9; 21	50	20
939 . .	43	9; 21	50; 20	..
940 . .	43	9; 21; 20	50	..

e above grouping shows that with this variety rootstock No. 43 (*kharna* is differentiated from the rest in that the trees of the Sangtra local are extremely vigorous even from their nursery stage and that this has been maintained throughout the period covered by this report. order of vigour are trees on rootstocks 9 and 21— an order which re-unchanged for all the four years. By 1940, however, one more root-viz. No. 20, has jumped up in this group. In the third and fourth the various rootstocks did not materially change their order of vigour first three years but by 1940, No. 50 alone remained in the third group. otstock may, therefore, ultimately prove to be a dwarfing rootstock gtra local scion variety.

Grapefruit (*Marsh Seedless*).—The mean data and significant differ-the 5 per cent level are compiled in Table V, which shows the relative three-year old trees of this variety as influenced by different root-

TABLE V

Performance of grapefruit (Marsh Seedless variety) with certain rootstocks apogamic origin

Year	Average circumferential measurements in cm. for root-stock numbers					General mean	S. E.	Signif cant di erence P=0·
	43	20	47	50	9			
1937 . . .	3·99	3·72	3·75	3·19	2·82	3·50	0·158	0·5
1938 . . .	5·43	5·43	5·02	4·42	4·25	4·91	0·208	0·6
1939 . . .	10·36	10·18	9·27	8·06	8·30	9·18	0·335	1·0
1940 . . .	18·7	18·3	16·6	14·7	12·4	16·12	0·477	1·5

The grouping of the various rootstocks, based on the statistical examination of the data given in Table V above, is made as under :—

Year	Group 1	Group 2	Group 3	Group 4
1937. . .	43; 47; 20	50; 9	..	..
1938. . .	43; 20; 47	50; 9	..	..
1939. . .	43; 20; 47	9; 50	..	..
1940. . .	43; 20	47	50	9

It is evident that, in 1937, with grapefruit as the scion variety, the th rootstocks Nos. 43, 47 and 20 are associated with more vigorous tre while the remaining two, viz. 50 and 9, formed a class which proved to be l vigorous. The relative performance of the three vigorous rootstocks did n change in the following year except that the order of vigour of stocks 47 a 20 in group 1 is reversed. A year later, viz. the beginning of 1939, the or of vigour of rootstocks in group 1 still remained unchanged, although a slig change occurred in group 2. By the beginning of 1940, however, the fi rootstocks under trial differentiated into four different groups with regard their influence on the vigour of grapefruit scion. Thus, grapefruit trees stocks 43 and 20 are of greatest vigour, those on 47 are of medium vigo while those on 50 and 9 are dwarf notwithstanding the fact that No. 9 is sig ficantly more dwarfing than No. 50.

Scion-stock combinations of set B with different scion varieties

1. Malta local.—The mean data and significant difference at the 5 p cent level are compiled in Table VI, which shows the relative size of thr year old trees of this variety as influenced by different rootstocks.

Local Malta on *mokari*

Table VI

e'ormance of Malta local variety with certain rootstocks raised by the rooting of stem cuttings

Year	Average circumferential measurements in cm. for rootstock numbers				General mean	S. E.	Significant difference for $P=0\cdot05$
	20	43	50	9			
. . . . .	4·08	4·65	5·36	3·60	4·18	0·357	1·12
. . . . .	6·09	6·09	6·66	4·74	5·89	0·30	0·94
. . . . .	11·49	11·39	10·63	8·36	10·47	0·36	1·14
. . . . .	19·1	19·0	16·4	13·1	16·91	0·46	1·47

The grouping of the various rootstocks, based on the statistical examina- n of the data given in Table VI, is made as follows :—

Year	Group 1	Group 2	Group 3
1937	50; 43	20; 9	..
1938	50; 43; 20	9	..
1939	20; 43; 50	9	..
1940	20; 43	50	9

The grouping of rootstocks shows that at the nursery stage in 1937, they l into two groups only. In group 1 occur the rootstocks 50 and 43 which associated with more vigorous trees of the Malta local scion. The trees rootstocks 20 and 9 form a less vigorous class. One year after planting, . in 1938, rootstock 20 had moved from group 2 into group 1, but the order vigour of the two rootstocks in group 1 did not change. In 1939, the ler of vigour of rootstocks in group 1 changed considerably. Thus, tstock 50, which occupied 1st position in 1937 and 1938, went to the t position and rootstock 20, which occupied last position in 1938, came to the emost rank. However, one should not lose sight of the fact that, despite change in the order of vigour of these rootstocks, they are statistically ntical, but this abrupt behaviour of stock No. 50 promises further segrega- n among the varieties in this group. Rootstock No. 9, however, remained group 2 as before. In 1940, rootstock 50 dropped back to group 2 but the naining two stocks in group 1 maintained their performance. It cannot foretold which of the two rootstocks in group 1 will ultimately prove to the most vigorous, but it would appear that stock No. 9 is likely to prove warfing stock for this scion variety more so than any other, and that stock . 50 may also prove dwarfing to this variety.

2. Sangtra local.—The mean data and significant difference at the 5 cent level showing the relative size of three-year old trees of this variety influenced by different rootstocks are compiled in Table VII.

Table VII

Performance of Sangtra local variety with certain rootstocks raised by the rooti of stem cuttings

Year	Average circumferential measurement in cm. for rootstock numbers				General mean	S. E.	Significant difference for $P=0\cdot05$
	43	20	9	50			
1937	5·76	2·39	2·48	4·23	3·72	0·301	0·95
1938	7·09	4·20	4·07	5·78	5·29	0·468	1·48
1939	13·24	9·71	10·07	11·02	10·99	0·335	1·06
1940	21·1	16·9	16·8	16·6	17·8	0·48	1·5

The grouping of various rootstocks, based on the statistical examinatio of the data given in Table VII, is made as follows :—

Year	Group 1	Group 2	Group 3
1937	43	50	9; 20
1938	43; 50	..	20; 9
1939	43	50; 9	20
1940	43	20; 9; 50	..

The data show that throughout the four-year period, trees of Sangtra scion variety on rootstock No. 43 are more vigorous than on the remaining three rootstocks. Rootstock No. 50, which proved next in order of vigour during the first three years, had, by the end of the fourth year, proved a dwarfing rootstock. No. 20, on the other hand, which was dwarfing as compared with others during the first three years, was eventually shown to have an invigorating effect. At the end of four years, Nos. 20, 9 and 50 are not significantly different from one another and, as a class, they are significantly less vigorous than No. 43.

3. Grapefruit (*Marsh Seedless*).—The mean data at the 5 per cent level are compiled in Table VIII which gives the relative size of three-year old trees of this variety as influenced by different rootstocks.

Table VIII

Performance of grapefruit (*Marsh Seedless*) *with certain rootstocks raised by the rooting of stem cuttings*

Year	Average circumferential measurements in cm. for rootstock numbers				General mean	S. E.	Significant difference for $P=0\cdot05$
	43	20	50	9			
1937	6·11	3·65	4·88	4·15	4·70	0·324	1·03
1938	7·75	5·50	5·71	5·61	6·13	0·380	1·21
1939	12·94	11·39	10·04	9·77	11·03	0·4	1·28
1940	21·2	20·3	15·8	15·5	18·23	0·375	1·2

The grouping of various rootstocks, based on the statistical examination the data given in Table VIII, is made as follows :—

Year	Group 1	Group 2	Group 3
1937	43; 50	9; 20	..
1938	43	50; 9; 20	..
1939	43	20	50; 9
1940	43; 20	..	50; 9

At the time of planting, i.e. at one-year old, the rootstocks 43 and 50 ere both associated with vigorous trees of the Marsh Seedless grapefruit ariety, while the remaining rootstocks, viz. 9 and 20, formed a second class hich differed from them in this respect. By the end of the next year, ootstock No. 43 alone remained in the vigorous group, and the remaining ree fell into group 2. In 1939, viz. two years after planting in the orchard, further differentiation took place in the rootstocks of group 2, by which ees on No. 20 became significantly more vigorous than those on either of o. 50 or 9. By 1940, trees on rootstock No. 20 became still more vigorous, d they are now nearly as vigorous as those on rootstock No. 43, whereas ootstocks No. 50 and 9 appear to be dwarfing ones.

Discussion

Rootstock No. 43

The performance of rootstock No. 43 [*Kharna khatta* (*C. karna Raf.*) nonyms : *Id* lemon(Poona, Bombay), *Soh sarakar* (Assam), *Mokari* (Renala hurd, Punjab) is outstanding in that it is associated with the most vigorous ees of all the three scion varieties budded on it. This is true for both seed- ng and cutting material. It differentiates, in this respect, from most of the maining rootstocks as early as one year after budding. The vigorous growths trees on this rootstock, coupled with the fact that its seedlings are usually for budding earlier than those of other varieties, indicate that, from the rseryman's standpoint, it is a rootstock which may become widely used cause, other things being equal, good nursery trees of a given scion variety n be produced relatively early. Furthermore, the consistent behaviour of ions on this rootstock for the first four years after budding strengthens the ew that, as compared with other varieties included in these trials, this one ay ultimately produce trees of the largest size. This point is of special gnificance in so far as it holds good for all the three scion varieties employed.

Brown [1920] reported a similar invigorating influence of *kharna* rootstock hich, according to the photograph of fruit in Plate VI, fig. 1 presented by m, appears to be of the same variety as *kharna khatta* employed in the esent investigations. Brown, however, translated this as rough lemon, a riety from which it differs in almost every respect. It would appear, there- re, that Brown did not employ the true rough lemon in his trials, although has reported the results of *kharna khatta* as being due to rough lemon. The sults of Brown have also been quoted by subsequent workers [Gardner *al.*, 1922] as the effects of rough lemon rootstock upon scion growth, a petition of which should be avoid.

So far as the present authors are aware, *kharna khatta* as a rootstock ha not been employed in other citrus-growing countries of the world, and it is ver probable that this species is a native of India. Its performance in these tria warrants an extension of its use on an experimental scale in this countr and elsewhere.

2. Rootstock No. 20

The use of this rootstock [*jatti khatti* or rough lemon (*C. limonia* Osbeck synonyms : *Khatta* (Renala Khurd and Lahore, Punjab) *Khatti* (Lyallpur an Shahdara, Punjab)] has been investigated in almost every citrus-growing coun try of the world. It should, however, be clearly understood that this rootstoc was not employed by Brown [1920] : Shrivastava [1920] and Prayag [1920 in their investigations in North-West Frontier Province, Central Provinces an Bombay and that *Id lemon* and *jamburi* said to be the varieties of rough lemo [Imp. Bur. Fruit Production, Tech. Com., 1932] have nothing in common wit the real rough lemon of South Africa, California and Florida, etc. [Coit, 1927 Hume, 1930 ; Powell, 1930]. It follows, therefore, that no work has yet bee done anywhere in India to elucidate the influence of rough lemon on the com mercially grown citrus scion varieties of this country.

As a result of the satisfactory growth of trees on rough lemon in most parts of the citrus world, it is the one most used in South Africa [Marloth, 1938 Powell, 1930]. In Arizona, California and Java [Coit, 1927 ; Marloth, 1938 Toxopeus, 1936] it is used to a limited extent. In Florida [Batchelor an Webber, 1939 ; Coit, 1927 ; Hume, 1930 ; Marloth, 1938] it is the main rootstock for very sandy soils although, according to Davis [1928], it thrives equally well on heavy loams. In Dominica, rough lemon has proved to be a good stock for acid limes [Imp. Bur. Fruit Product. Tech. Com., 1932]. In Australia [Marloth, 1938] it is employed extensively, and in the Punjab it is also one of the widely used rootstock varieties. Cheema [1929] advises rough lemon as the most suitable rootstock for lemons in western India, though the species actually used is different from real rough lemon. It is evident from the above, therefore, that with rough lemon the problem appears to be one of adaptability to local soil and climatic conditions rather than congeniality be tween stock and scion, since cases of absolute failure or imperfect union have not been reported from anywhere.

The data presented in the foregoing section show that rough lemon is a promising rootstock and its growth influence in case of the sweet orange (Malta) and grapefruit scions may ultimately be in line with *kharna khatta*, but in the case of Sangtra scion variety it may not prove equally vigorous. It is, however, significant that even with sweet orange and grapefruit scions, it did not produce as vigorous nursery trees in the same period as was done by some other rootstocks. All the same, the experience of workers in other countries [Coit, 1927 ; Hume, 1930], that this rootstock is associated with vigorous vege tative growth of young trees, is also corroborated by the data here reported.

3. Rootstock No. 50

Sweet lime [*mitha* (*C. aurantifolia* var. Swingle)] is, perhaps, indigenous to India. On its own roots, it is quite vigorous and spreading but when used

a rootstock for sweet orange, mandarin and grapefruit, the resulting trees re dwarfed. It is a favourite with nurserymen throughout the Punjab, partly ue to the prevalent belief that it improves the texture and quality of fruit f the scion varieties worked on it, and partly to its ability to root readily from em cuttings producing well grown nursery stock in a comparatively short eriod. The latter point concerns mainly the nurseryman, who is chiefly nterested in the production of plants in a short space of time, but the former oint concerns the grower and the fruit industry in general and is, therefore, nore worthy of consideration and experimentation.

The data show conclusively that, with all the three varieties in set A, sweet me rootstock behaves as a dwarfing type. In set B, however, the trees on his stock are vigorous when young, but by the beginning of 1940, the trees on ome other rootstocks had significantly outgrown them. The difference in the igour of scion varieties in sets A and B, brought about by this rootstock for the rst few years was, therefore, of a transitory nature and was mainly due to the ncreased vigour of nursery stock in set B at the time of budding. Evidently herefore the nursery stock of sweet lime, raised by the rooting of cuttings, ecame fit for budding comparatively much earlier than that raised from seed Not only this, with the exception of *galgal* (hill lemon) which is not employed n these trials, sweet lime cuttings resulted in nursery stock of a better size nd vigour than that of the remaining stock varieties under trial in set B. Since time of budding was the same in sets A and B, the stocks in set B made nuch better growth than those in set A and even within set B the sweet lime tock made better growth than others in view of its better rooting capacity nd was consequently at an advantage to induce better growth of scion buds laced in it. This initial advantage, however, was not maintained and this ootstock must now be regarded as dwarfing in character as in the case of set A. All the three scion varieties worked on sweet lime in sets A and B are some vhat dwarfed, and these effects are in general agreement with the results ob ained by Brown [1920] in India and are also in accord with the experience of growers in south eastern Mediterranean countries, especially in Palestine Hodgson, 1931; Powell, 1930], where Jaffa or Shamouti variety of sweet range is mainly grown on sweet lime.

4. Rootstock No. 21

According to Bonavia [1880] this rootstock, *[sass.eran* (*C. japonica* Thumb)] esembles in character the *reshmi* orange of the United Provinces, India, and s not a true mandarin although it is called mandarin in Ceylon. It was intro luced into the Punjab through the courtesy of the Curator, Royal Botanic Gardens, Paradeniya, Ceylon, and was included only in set A (rootstocks of apogamic origin) as the cuttings did not root well On its own roots, this root stock is comparatively dwarf, but when used as a rootstock for sweet orange (Malta local) it has produced maindens of greater vigour than those of the most vigorous known rootstocks. On transplanting to the orchard, the trees on this rootstock naturally received the greatest setback and some of them even died, but the remaining ones are now growing well. On the other hand, when used as a rootstock for mandarin (Sangtra) it produced maindens of medium vigour only, which when transplanted grew very well indeed. Furthermore, the results (Tables III and IV) show that, both with sweet orange and mandarin as

the scion varieties, this rootstock maintained its nursery performance, viz. that of producing vigorous trees in case of the former and dwarf trees in case of the latter throughout the course of these investigations. This differential response may be partly correlated with the fact that the union of this rootstock with Malta scion is perfect, but with Sangtra scion the stock stem outgrows the scion stem.

5. Rootstock No. 9

This species [*mokari* or citron (*Citrus medica* Linn.), synonyms : *Turanj* (Renala Khurd, Punjab), *Sak limboo* (Poona), *Nattaran* (Ceylon), *Sohmad* (Assam)] is a native of India [Powell, 1930]. It has two forms : one where the rind is very rough, corrugated and is orange on ripening (C. Mahalung, Poona) and the other where the rind is smooth and is yellow on ripening. It is the latter form that has been employed in the trials reported here.

The nursery performance of this species is equal to that exhibited by our best rootstocks. It is easily grown from cuttings and both cutting and seedling stocks reach the budding stage as quickly as those of any other stock. Probably the greatest point in its favour is the fact that variability in the seedbed with regard to the height and vigour of seedlings is low and in consequence only a small percentage of seedlings has to be discarded at the transplanting time. The main disadvantage appears to be its extreme susceptibility to citrus canker and gum diseases.

Out of the three scion varieties, viz. sweet orange (Malta local), mandarin (Sangtra local) and grapefruit, with which it has been tried as a rootstock, it has given good union only with mandarin while in the remaining two cases the scion portion has invariably outgrown the rootstock.

The data show conclusively that with sweet orange and grapefruit, where it is not quite compatible, its effect is that of dwarfing nature but in case of Sangtra local scion the trees on this rootstock are fairly vigorous. In this respect, therefore, like *nasnaran* it has responded differently with different scion varieties. It has been largely used as a rootstock in Egypt [Brown, 1936] with the result that trees budded or grafted on it remain inferior in vigour and resistance to diseases. This experience of Egyptian growers is in conformity with the results obtained in the Punjab.

6. Rootstock No. 47

As far as could be ascertained, shaddock [*chakotra* (*Citrus maxima* Merrill)] has never been employed as a rootstock in the Punjab for orange, mandarin and grapefruit. However, in view of the remarks of Webber [1925] that shaddock has been favourably commented on as a rootstock for grapefruit in South Africa, it was considered desirable to include this in the citrus rootstock trials, especially in the case of grapefruit.

It has made a good union with grapefruit and the results show that trees on this stock are fairly vigorous. Although the trees have only completed three years in the orchard, some of them growing on this rootstock are severely affected with mottle leaf. Whether it is purely accidental that the portions of the land, on which the trees of this scion-stock combination are planted, are deficient in certain elements causing mottle leaf or whether this rootstock itself is responsible for this malady cannot at present be determined.

Summary

The influence of certain rootstocks on the vigour of young stem-budded ions of sweet orange (Malta), mandarin (Sangtra) and grapefruit has been udied at Montgomery, Punjab, for the years 1937-40.

The results show that :—

(*a*) *Kharna khatta* (*C. karna* Raf.) is associated with the most vigorous trees irrespective of the scion variety budded on it.

(*b*) *Jatti khatti* or rough lemon (*C. limonia* Osbeck) is also associated with vigorous-growing trees, but it does not equal *kharna khatta* in this respect.

(*c*) *Mitha* or sweet lime (*C. aurantifolia* var. Swingle) appears to be a dwarfing rootstock for each of the three scion species budded on it.

(*d*) *Nasnaran* (*C. japonica* Thumb) and *mokari* or citron (*C. medica* Linn.) both appear to be variable in their influence as rootstocks. For instance, sweet orange on *nasnaran* has proved vigorous, but mandarin trees on this rootstock are decidedly dwarfed. Similarly, plants of sweet orange and grapefruit are dwarf on *mokari*, but those of mandarin on the same rootstock are vigorous.

(*e*) Grapefruit trees on *chakotra* or shaddock (*C. maxima* Merrill) show mottle leaf but it has not yet been determined whether this is due to soil or to rootstock.

The vigour of different scion species has been shown to be variable n one and the same rootstock in case of two rootstock species, namely *nasnaran* nd *mokari*. The terms vigorous and dwarf usually assigned to rootstocks ould be used only in connection with specified scion varieties.

The vigour of an unworked rootstock is no criterion of its vigour as a ootstock when grafted with certain scion varieties. For instance, *nasnaran* hich is comparatively dwarf on its own roots has, when used as a rootstock r sweet orange, given rise to trees equal in vigour to those on the so-called igorous rootstocks. *Mitha* (sweet lime), on the other hand, is quite vigorous nd spreading on its own roots but, as a rootstock, it has dwarfed all the scion arieties budded on it in spite of its having made good union with the scion arieties. *Mokari* (citron), which is fairly dwarf on its own roots, has roduced Sangtra plants of good vigour.

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UTILIZATION OF VIRGINIA TOBACCO SEED IN THE MADRAS PROVINCE

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THERE is an area of about 3,00,000 acres under tobacco in the Madras province, of which nearly 1,50,000 acres is confined to the Guntur district 50,000 acres to the Kistna and Godavari districts and the rest to the other parts of the province. Out of this, about 1,25,000 acres are grown with Virginia tobacco. Nearly 80 per cent of this area, in turn, is in the Guntur district and the rest in the Kistna and Godavari districts along the borders of the two rivers. The crop is allowed to flower and pod freely—unlike *natu*, the local cigar variety, which is invariably topped—in nearly 90 per cent of the Virginia tobacco-growing area to impart proper texture, body and colour to the leaf and make it fit for cigarette manufacture.

Seed, its oil content and general properties

An average crop of Virginia tobacco yields about 150-200 lb seed per acre. After the leaf picking is over and before the crop is pulled, sheep and goats are allowed to eat the pods freely when ripe, and they seem to relish it and do well. Majority of the seed pods are, however, burnt along with stalks which at present form the main fuel in use in all Virginia tobacco-growing areas. From preliminary trials it was found that the seed contained some oil and hence it was thought desirable to find some use for it. On extraction by the cold-drawn process in the country wooden mill (*chekku*) and by the hot-drawn process generally adopted for extracting castor oil, oil to an extent of 25-30 per cent could be got. The cold-drawn oil was thin, transparent, light yellow, pleasant smelling, agreeable to taste, and almost identical with first class gingelly oil. The hot-drawn oil was thin, slightly turbid yellow, pleasant smelling, and slightly bitter in taste. The seed and cake were readily eaten by sheep, goats and cattle. Viands made out of the cold-drawn oil obtained from well-washed seeds were not different from those made out of gingelly oil. Those prepared in the hot-drawn oil and in cold-drawn oil extracted from unwashed seeds were rather bitter to taste. The extraction of oil by the cold-drawn process as is done in the case of gingelly seeds will prove a good cottage industry in the Virginia tobacco areas, but there are not enough country wooden oil mills available in the areas for the purpose. Extraction by the hot-drawn process in the hand presses used for extracting castor oil is quite possible. Tobacco seeds, however, seem to

t a higher temperature and more pressure than castor seed for efficient raction and to achieve this some structural changes in the oil presses now se may be necessary. When the seed is pressed by this process, it should crushed in flour mills before pressing for efficient extraction of oil.

mical investigations of seed oil and cake

Samples of oil and cake from the same batch were sent to several analysts India and the results supplied by them are incorporated in Tables I. For purposes of comparison, the results obtained by investigators other parts of the world on the subject are produced in Tables IV and V.

TABLE I

esults of analysis of Guntur Virginia tobacco seed for food and mineral values

(By the Government Agricultural Chemist, Coimbatore)

Head of analysis	Per cent
. Food values—	
Moisture	6·05
Ash	3·76
Crude proteins (N × 6·25)	23·88
Ether extractives	35·77
Crude fibre	16·77
Carbohydrates (by difference)	13·77
Total	100·00
Insolubles	0·31
Albuminoids (true proteins)	22·80
Nicotine	Absent*
Mineral values—	
Lime (CaO)	0·21
Potash (K_2O)	0·94
Phosphoric acid (P_2O_5)	1·09
Nitrogen (N)	3·82

* As observed by the Imperial Agricultural Chemist, New Delhi

The results obtained and the conclusions drawn therefrom were general conformity with those obtained elsewhere and establish the fact th Guntur Virginia tobacco seed contains about 35-37 per cent of oil, is free fr nicotine and can be used as an edible or semi-drying oil and for soap maki or for illumination purposes. Its uses as an edible oil in Bulgaria are report by Jamieson [1932] and as a semi-drying oil by Paris [1920] and Pyat-nitz [1929]. Samples of hard and soft soaps, prepared at the Kerala Soap Institu Calicut indicate that the oil can be used for this purpose with success.

The cake contains about 30-35 per cent crude proteins, 29-34 per ce albuminoids, 16-17 per cent ether extractives, about 27 per cent carboh drates, and is free from nicotine. It compares favourably in its fo values with gingelly cake so extensively used for cattle feed in this provin (Table VI) and cattle eat the cake freely. Feeding trials substituti tobacco seed cake for groundnut cake were conducted over a period of fi weeks at the Agricultural Research Station, Guntur. The feeding d not bring about any adverse effects on the animals. They looked norm during the feeding trials and after. It is reported [Orlov, 1933] that the cal is extensively used for horse-feed. As the cake contains about 5 per ce nitrogen (N), 1·6 per cent phosphoric acid (P_2O_5) and 1·15 per cent pota (K_2O), it can be used as a good nitrogenous organic manure comparing favou ably with an average sample of castor cake.

If facilities for the extraction or marketing of the oil do not exist, th seed can by itself be used as cattle food as it contains about 24 per cent crud proteins, 23 per cent albuminoids, 36 per cent ether extractives, 14 per ce carbohydrates, and is free from nicotine. As the seed has a thick seed-coa it should be soaked in water for two days, washed well, ground into a past like horse-gram and fed to cattle.

Further studies on seed oil

Though the oil is fit for use for soap making and for illumination o edible purposes, its use as a semi-drying oil seems most advisable as th Madras province does not produce any other drying or semi-drying oil wort the name. For the supply of linseed oil which is the chief oil used for paint in the province, it depends entirely on northern India, and the typica drying oil *tung* oil - is primarily imported from Burma and China.

The percentage composition of the different fatty acids in tobacco seed oil, linseed oil and *tung* oil are produced in Table VI, and some of their physica and chemical constants are given in Table VII. While *tung* oil stands unique in its composition and drying properties, linseed oil comes intermediate and tobacco-seed oil next in drying properties. The total absence of linolenic acid in tobacco-seed oil makes it dry somewhat slower, but its absence enable white paints mixed with tobacco-seed oil to continue to remain white, whil they turn yellowish when mixed with linseed oil. While tobacco seed oil ca be clarified to a practically colourless liquid, linseed oil cannot be so manag ed. These two characters of the oil make it eminently suited for the prepa ration and application of white paint and white enamels in preference t linseed oil.

TABLE II

*Some important physical and chemical constants of Gunter Virginia tabocco seed oil***

Analysed by	Specific gravity at 30°C.		Refractive index at 40°C.		Acid value		Saponification No.		Iodine No.		Butyro-refracto-meter at 40°C.		Nicotine	
	C. D.	H. D.	C. D.	H. D.	C. D.	H. D.	C. D.	H. D.	C. D.	H. D.	C. D.	H. D.	C. D.	H. D.
1. Indian Institute of Science, Bangalore	...	...	1·46850	1·46850	0·800	0·595	190·4	190·5	124·4	124·9	...	...	Absent	Absent
2. Imperial Agricultural Chemist, New Delhi	...	...	...	...	...	...	...	...	137·1	138·7	...	...	..	...
3. Government Food Analyst, Guindy	...	...	...	...	0·55	0·39	...	...	142·0	142·0	64·7	65·3	...	...
4. Government Agricultural Chemist, Coimbatore	...	...	...	...	...	...	169·0	191·4	136·6	124·6	...	...	...	..
5. Superintendent, Kerala Soap Institute, Calicut	..	0·912	...	1·4725*	...	...	...	188·6	...	142·5	...	...	...	...
6. H. B. Technological Institute, Cawnpore	...	†0·9153	...	1·4684	...	...	...	186·4	...	154·5	...	...	...	...

**C. D. = Cold drawn ; H. D. = Hot drawn

* At 15·5°C.
† At 30°C.

TABLE III

Results of analysis (on dry basis) of Guntur Virginia tobacco seed cake for and mineral values as against an average sample of gingelly cake

Particulars	Tobacco seed cake, Analysed by						Gingelly Analys Govt. Chem Coimb
	Impl. Agrl. Chemist, New Delhi		Govt. Food Analyst, Guindy		Govt. Agrl. Chemist, Coimbatore		
	C. D.	H. D.	C. D.	H. D.	C. D.	H. D.	C. I
A. Food values (per cent)							
Moisture .	5·87	5·22	..	..	..	..	..
Ash . .	..	..	..	..	10·29	5·53	10
Crude proteins (N × 6·25)	30·75	35·81	..	..	30·58	34·13	37
Ether extractives	..	..	..	..	16·00	17·08	17
Crude fibre .	..	..	..	..	16·60	16·07	3
Carbohydrates (by difference).	..	..	..	..	26·53	27·19	30
Total .	..	..	..	..	100·00	100·00	100
True proteins or albuminoids	..	..	..	..	28·52	33·81	35
Oil . . .	..	..	11·2	14·5	..	..	..
Nicotine . .	Absent	Absent					
B. Mineral values (per cent)					On sample weight		
Lime (CaO) .	..	..	..	..	0·65	0·22	
Potash (K_2O) .	..	..	..	..	1·13	1·17	
Phosphoric acid (P_2O_5)	..	..	2·5	2·6	1·85	1·41	
Nitrogen (N) .	4·92	5·73	4·6	5·2	4·89	5·46	

C. D. = Cold drawn ; H. D. = Hot drawn

** *Protein contents*—

Gingelly cake from shelled seed . 33·13 } G. A. C., Coimbatore

Gingelly cake from un-shelled seed . 44·31 }

Table IV

nt characters of the tobacco seed oil as determined by investigators in other parts of the world

ne of investigator	Ref. No.	Saponification value	Iodine value	Remarks
ola and Sourti [1904]	1	190·00	118·60	
secker and Brezina [1919]	2	196·40	131·60	
[1920] . . .	3	194·60	135·46	Used as edible and semi-drying oil
nitzkii [1929] . .	4	200·70	135·34	Mixed with driers and pigments ; rather slow-drying films were obtained
zov and Grashin [1930]	5	190·49	139·74	
rts and Schutte [1934]	7	182·00	152·00	Nicotine absent
a and Dedinszky [1934]	8	190·50	..	

Table V

of analysis of tobacco seed cake for the food values (on dry basis) as determined by investigators in other parts of the world

Particulars	Ref. 8	Ref. 10
	Per cent	Per cent
re	3·38	8·66
ash	4·97	14·43
proteins	34·05	38·31
fat	24·33	10·69
fibre	23·64	17·97
in (digestible)	..	36·37
ks.	No tobacco odour	Has been successfully used for horse feeding ; nicotine absent

TABLE VI

Percentage composition of different fatty acids in tobacco seed oil as compared those in linseed oil and tung oil

Name of acid	Tobacco seed oil			Linseed oil	Tung oil
	Ref. No. 4	Ref. No. 7	Ref. No. 11	(Ref. No. 12)	(Ref. No. 13)
	Per cent	Per cent	Per cent	Per cent	Per cent
Oleic	21·70	16·20	26·37	5·00	10·0
Linoleic	60·00	70·40	60·23	48 to 59	..
Linolenic	..	..	..	21 to 32	..
Palmitic	9·60	3·10	7·03	10·00	..
Stearic	..	4·80	3·04		..
Elaeostearic	..	..	..	..	80·0
Glyceryl radicle	..	..	..	4·60	..
Unsaponifiable matter	1·20	1·25	1·41	..	..
Remarks	Alcoloids and linolenic acid absent	..	..	..	..

Economic aspect

At an estimate of 175 lb. seed per acre and 25 per cent of extracta oil in it, the province can supply about 8,800 tons of seed, or 2,200 ton oil and 6,600 tons of cake per annum if the whole quantity of seed produ is gathered. If the oil is valued on par with the present price for lins oil and cake on par with gingelly cake, the province can get annually riched by 13 lakhs of rupees, if all the Virginia tobacco seed produ is utilized.* This will incidentally make the province, at least partly, s sufficient in its requirements for semi-drying oils.

Several paint firms have placed bulk indents for the supply of oil. Th quotations are, however, rather low, and the matter is under correspondenc A special grant of Rs. 500 has been sanctioned by the Madras Government start business in this line.

*An acre of Virginia tobacco contains about 5,000 plants and seed from abou plants will be more than sufficient to produce seedlings to plant an acre.

TABLE VII

Important physical and chemical constants of Guntur Virginia tobacco seed oil, linseed oil and tung oil, as noted in their raw form

Particulars	Virginia tobacco seed oil (Guntur)	Linseed oil*	*Tung* oil*
gravity at 15·5°C.	0·912 to 0·915	0·931 to 0·941	0·939 to 0·943
tive index at 20°C.	1·4684 to 1·4725	1·4742 to 1·4754	1·518 to 1·522
number	0·39 to 0·80	Up to 10	Up to 5
ification number	186 to 191	189 to 196	189 to 195
onifiable matter	1·2 to 1·41**	0·8 to 2·0	Up to 0·75
value	124 to 155	170 to 185	155 to 167

ference 13
ble IV

re work

Bulk samples of the oil have been sent to several leading firms manuring enamels, paints and varnishes, throughout India and their reports awaited. Preliminary investigations made in the Sodhan Laboras, Tenali, Guntur district, on the industrial utilization of the oil are iently encouraging. Manurial trials with cake were arranged on all rtant crops grown under dry, irrigated and wet conditions during the and they will be further elaborated during the next year. The techue of crushing is being studied for better extraction. If sufficiently enaging reports are received from the different manufacturing firms, colon of seed and establishment of market for seed, oil and cake will be conplated. In the meantime, necessary propaganda is being undertaken tilize the seed as cattle food.

CONCLUSIONS

Virginia tobacco seed extensively produced in the Guntur, Kistna and lavari districts contains nearly 35-37 per cent of edible and semi-drying

The oil can with advantage be used as semi-drying oil.
The cake can be fed to cattle or used as manure.

Till a market for seed, oil and cake is established, the seed can be to cattle.

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